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**ENVIRONMENTAL REPORT
FOR CALENDAR YEAR 1989**

BY

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MASTER

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1.0 INTRODUCTION

1.1 General

This report gives the results of the environmental activities and monitoring programs at the Princeton Plasma Physics Laboratory (PPPL) for Calendar Year 1989 (CY89). The report is prepared to provide the U.S. Department of Energy (DOE) and the public with information on the level of radioactive and nonradioactive pollutants, if any, added to the environment as a result of PPPL operations. The objective of the environmental report is to document evidence that DOE facility environmental protection programs adequately protect the environment and the public health.

The Princeton Plasma Physics Laboratory has engaged in fusion energy research since 1951 and in CY89 had two large tokamak devices in operation; namely, the Princeton Beta Experiment-Modification (PBX-M) and the Tokamak Fusion Test Reactor (TFTR). A new machine, the Compact Ignition Tokamak (CIT), is under conceptual design, and its draft Environmental Assessment (EA) report required by the National Environmental Policy Act (NEPA) has been forwarded to DOE/Headquarters (HQ). The goal of the U.S. Magnetic Fusion Energy Research Program is to develop and demonstrate the practical application of fusion power as an alternate energy source.

The Princeton Beta Experiment (PBX), the predecessor of PBX-M, after achieving a greater than 5% beta (ratio of plasma pressure to magnetic pressure) in CY84 experiments, was shut down at the end of 1985 to undergo modifications to permit further examination of theoretical predictions on plasma shaping and stabilization of kink modes by means of a close-fitting conducting wall. The addition of new coils and stabilizer plates within the vessel, new power supplies, and a new control system began in 1986. The modified device, PBX-M (Fig. 1), came back into operation in October 1987. In CY88, an indentation of the plasma of 25% was achieved, lower $q(a)$ values obtained, and H-modes at lower power attained. In CY89, the effectiveness of the passive plates in stabilizing kink modes and access to higher plasma pressure ($\beta \sim 6.8\%$ and $\beta > 4 \times \beta_{\text{Troyon}}$) were assessed. A Safety Assessment Document (SAD) was published for the PBX in 1984 [F184] which indicated that the PBX did not pose any potential environmental concerns. A new SAD published for the PBX-M reached the same conclusion [St88a].

The TFTR (Fig. 2), which had its first full year of operation in CY83, had an increase in total neutron production in CY87 to a yearly total of 3×10^{18} [He88], in CY88 to a yearly total of 9.04×10^{18} [He89], and in CY89 of 6.4×10^{18} (Ja90). The higher neutron production has increased the activation level of the machine to the point where health physics surveys are required in the test cell following a machine run and before any personnel entry is permitted for inspection, routine maintenance, or installation work. In addition, tritium from deuterium-deuterium (D-D) reactions, which was absorbed in graphite and measured during the opening of the vessel in 1987 and 1988, posed the first known health physics contamination challenges for any tokamak operations. The experience gained from the 1987 opening was beneficial for the similar opening in 1988 and will help to streamline operations for the planned 1990 opening.

The TFTR is a toroidal device in which a deuterium-tritium (D-T) plasma will be magnetically confined and heated to extremely high temperatures by neutral-beam injectors. A major achievement in 1986 was an increase in neutron production and fusion power by operating in what is now called the "supershot" pulse mode. Using this technique, a new record temperature of greater than 300 million degrees Celsius was achieved. Ion Cyclotron Radio-Frequency (ICRF) heating became operational in 1988. The D-T operations were scheduled to begin in 1990; however, reprogramming and a budget cut announced in November 1988 have resulted in a 2 to 3 year schedule delay for D-T operations. The safety analyses completed for this program are addressed in Safety Analysis Reports for the Project [PSAR78 and FSAR82]. In 1988, the Final Safety Analysis Report (FSAR) was being updated to reflect operational requirements and parameters using tritium. The initial reviews for the update, which began in CY88, were put on hold after the announced budget reduction. This effort will begin again in FY91.

Although PPPL operates as an unfenced site, with access controls for security purposes, it is considered to be open to the public for environmental purposes. This free access has necessitated a thorough evaluation of the on-site discharges as well as the potential for off-site releases of radioactive and toxic nonradioactive effluents. An extensive monitoring program, tailored to these needs, has been instituted and expanded over recent years. The PPPL radiological environmental monitoring program generally follows the guidance given in two DOE reports; namely, A Guide for Environmental Radiological Surveillance at U.S. Department of Energy Installations [Co81] and Environmental Dose Assessment Methods for Normal Operations at DOE Nuclear Sites (PNL-4410) [St82]. This includes adherence to the standards given in DOE Orders, in particular, DOE Order 5480.1A, Chapter XI

[DOE81], which pertains to permissible doses and concentration guides and gives guidance on maintaining exposures "to as low as reasonably achievable" (ALARA). On January 1, 1990, DOE Order 5480.11 guidelines will come into effect [DOE89]. While this order will not affect PPPL operations, the order will incorporate some changes in personnel monitoring requirements. Additional interim criteria were forwarded by memo [Mi85] and will be implemented as part of this order on January 1, 1990. Specific criteria for implementing these standards on TFTR are contained in a TFTR Operational Safety Requirement (OSR/TFTR/0-2F-C) (see Table 1).

An environmental survey was conducted in June 1988 by DOE/HQ as part of an intensive look at all DOE sites. No significant environmental concerns surfaced at PPPL as a result of this audit. An oil spill in 1988 by an outside vendor has led to a project of incorporating its cleanup with underground storage tank leak elimination and their replacement. In addition, groundwater contamination on adjoining properties has prompted the Laboratory to initiate a program to determine whether or not this contamination will affect our site.

The emphasis of the radiation monitoring program has been placed on exposure pathways appropriate to fusion energy projects at PPPL. These pathways include external exposure from direct penetrating radiation and eventually from airborne radionuclides, such as ^{41}Ar , ^{13}N , ^{16}N , and internal exposure from radionuclides, such as ^3H in air and water. Six major critical pathways are considered as appropriate (see Table 2). Prompt radiation, i.e., that which is emitted immediately during operations, was also considered and is being measured. The monitoring program, as envisioned by the TFTR Final Safety Analysis Report [FSAR82], has been updated to reflect the current environment around TFTR (see Table 3). At present, the radioactive pollutant potential to the environment by any pathway is essentially nonexistent. Small amounts of tritium are produced from D-D reactions [approximately 310 mCi (11.4 GBq) in 1989 if all neutrons were D-D produced]. A monitoring of the stack releases is planned for 1990. Low levels of tritium (exempt quantities, i.e., less than levels defined as radioactive materials by the Department of Transportation) are now detectable in pump oils. Also, tritiated water (HTO) was detected in the vacuum vessel air during the 1987 maintenance and upgrade period [St88b] and the subsequent 1988 opening, and some should be seen in the 1990 opening.

Preliminary meteorological considerations and associated methodology, which were established at the time of the installation of PPPL's first meteorological tower, were reported in Section 2 of the TFTR FSAR. Subsequently, improved methodologies were implemented

and a new meteorological tower was erected and began operation in November 1983 [Mc83]. The improved measurements and methodologies are being included in the updated FSAR being prepared for tritium operations. Data have been collected for six years using the monitors on the new tower. Wind-rose plots from the data for the first six years (1984-89) are shown in Figs. 3 and 4 [Ku89]. A tracer gas-release test was conducted during the period from July to September 1988 to look at site-specific air-diffusion parameters. These tests were commissioned to determine actual site conditions versus model predictions in relation to future activities. The test results indicated that actual dispersion and dilution of effluents in the vicinity of PPPL is enhanced by up to a factor of 16 over that predicted by Nuclear Regulatory Commission approved standard Gaussian diffusion models [St89a]. Additionally, as a result of these tracer gas-release tests, a 10-m wind speed and wind direction sensor is to be added to the meteorological tower in 1990 to monitor PPPL on-site meteorology more precisely. The U.S. Environmental Protection Agency (EPA) has been petitioned to use the more realistic χ/Q values from this test in the AIRDOS-EPA model used for the National Emission Standard for Hazardous Air Pollutants (NESHAP) calculations.

1.2 Description of the Site

The Princeton Plasma Physics Laboratory is located at the C- and D-sites of the James Forrestal Research Campus of Princeton University (Figs. 5 and 6). As shown in Fig. 7, the location is in central New Jersey within Middlesex County. The site is surrounded by undisturbed areas with virgin forest, open grass areas, an airplane runway, and a small brook (Bee Brook) running next to its eastern boundary. The closest urban centers are New Brunswick, 14 miles to the northeast, and Trenton, 12 miles to the southwest. Major metropolitan areas, including New York City, Philadelphia, and Newark, are within 50 miles of the site. As shown in Fig. 8, the municipalities of Princeton, Plainsboro, Kingston, West Windsor, and Cranbury, among others, are in the immediate vicinity of the site. Also, the main campus of Princeton University, located primarily within the borough of Princeton, is approximately three miles to the west of the site. The general layout of the facilities at the C- and D-sites of Forrestal Campus is indicated in Fig. 9; the specific location of TFTR is at D-site.

A demographic study was completed in CY87 as part of the requirement for the Environmental Assessment for the Compact Ignition Tokamak (CIT) [Be87a]. Other information gathered and updated from previous TFTR studies included socioeconomic information [Be87b] and an ecological survey [En87]. The demographic data were based on

the 1980 census and show both estimated and projected data out to the year 2010 (Tables 4 to 16 and Figs. 10 to 19) in a zone from 1 mile out to 50 miles.

The PPPL site is in the center of a highly urbanized region extending from Boston, Massachusetts, to Washington, D.C. The previous population projections for the States of New Jersey, New York, and Pennsylvania had indicated a substantial population increase within 50 miles of the PPPL site. The actual change from 1970 to 1980, as indicated by the census in these two years, was not as large as had been expected. In fact, the population in New York City and Philadelphia decreased. The Princeton area continues to experience a substantial increase in new business moving into the Route 1 corridor near the site. This increase, however, has not been as great as the projections had indicated. As a summary, population data were divided into annular sectors. It was prepared in 1986 for use with several standard codes used for the determination of off-site dose due to the release of activated air radionuclides and tritium [Ko86a]. Table 16 shows data supplied by the Princeton Forrestal Center on the population within one mile of the TFTR site. The numbers indicated have been divided by four to obtain an equivalent exposure for habitation [Ko86b].

2.0 SUMMARY

During CY89, there were no accidents, incidents, or occurrences that had a significant impact on PPPL facilities or program operations. The accidental overfilling of an underground storage tank (UST) during 1988, along with the discovery of residual hydrocarbons in the soil of an area used for unloading fuel oil trucks over the last 30 years, has the potential for a minor environmental impact and has resulted in a costly clean up in this area. Weed control and grass fertilization were previously applied under the direction of the Princeton University Buildings and Grounds Department. The work was done by University personnel or certified contractors in accordance with EPA regulations. In 1989, this work was carried out by PPPL staff utilizing subcontractors. Transformers and capacitors containing Polychlorinated Biphenyls (PCB) oils are being removed from service and disposed of in accordance with prepared schedules and EPA regulations. The Laboratory has an ongoing program to monitor, inventory, and dispose of PCBs and other potentially toxic materials.

Surface water analyses for both radioactive and nonradioactive pollutants have shown nothing above normally expected background values. The initial phase of a program for groundwater analysis was initiated in 1985. The U.S. Geological Survey (USGS) finished their drilling programs in 1986 but continue to monitor a bromine (NaBr) tracer test initiated

in the fall of 1986. Ambient tritium levels at less than 100 pCi/liter (3.7 Bq/liter) were measured in D-site well water. These data are in agreement with previous measurements by PPPL and the USGS [St88d]. Soil and vegetation samples were collected and analyzed as part of the continuing baseline studies. New groundwater monitoring wells were added in 1989 as a requirement for the groundwater part of our New Jersey Pollutant Discharge Elimination System (NJPDES) permit. Initial sampling of these wells indicated the presence of lead in two shallow wells next to the detention basin. This lead has been traced back to the painting of transformers in 1987.

Radiation exposure via airborne effluents into the environment is still at insignificant levels; however, a stack monitor for tritium is planned for 1990 to ensure compliance with new EPA regulations. From known D-D reactions, less than 310 mCi (11.4 GBq) was released in 1989. This included controlled tritium releases to the air and less than 0.5 mCi (18.5 MBq) to the sanitary sewer. Prompt radiation is detectable at extremely low levels during high-power pulses from TFTR. The integrated level at the site boundary, from TFTR operations, was less than 1 mrem (0.01 mSv) for CY89 for measured, prompt radiation plus postulated tritium releases and air activation [Gi90].

Off-site surface water, soils, and biota continued to be analyzed for radioactive baselines in CY89. Passive tritium monitors were tested on-site in 1986 and tested in a field modeling experiment in Canada in 1987 [Gr88a]. Most off-site placement of these monitors has been delayed by budget constraints resulting in program delays. One off-site monitor was in operation in 1989 along with four on-site monitors. These differential atmospheric tritium samplers (DATS) are high sensitivity monitors which are able to detect changes in the ambient levels (Gr88b).

3.0 MONITORING, ENVIRONMENTAL PROGRAM INFORMATION, DATA COLLECTION, ANALYSES, AND EVALUATION

The monitoring-program implementation has followed a phased approach commensurate with the potential hazards and the needs of an expanding program. Nonradioactive water-pollutant monitoring has been conducted for many years. A more extensive program, which began in 1979, presently includes eight surface water-sampling points (four on-site and four off-site). In addition, four groundwater sites (two former drinking water wells and two wells near the TFTR liquid effluent-collection tanks), along with the potable water-supply source were

monitored through November 1989. In November, two former wells were dropped from the program, and seven new wells were added as part of the New Jersey Pollutant Discharge and Elimination System (NJPDES) permit requirements. Monitoring for sources of potential radiological exposures is extensive. Real-time prompt gamma/neutron environmental monitoring began on the TFTR site in 1981 to establish baselines prior to machine operation. Four monitoring stations are located at the TFTR EZB. Neutron monitors were added at these locations at the end of CY84. Passive tritium monitors were added in CY87. Radiological-water samples are being collected at the same locations as the nonradioactive-sample points (see Figs. 20 and 21). Soil and biota samples are also being analyzed for tritium baselines. One off-site baseline tritium air monitor was added in CY89.

3.1 Radioactivity

3.1.1 Penetrating Radiation

Operation of the Princeton Beta Experiment-Modification (PBX-M) results in the production of some penetrating radiation (primarily bremsstrahlung X-rays and neutrons). Because the PBX-M has no roof shield, skyshine radiation (primarily neutron) is seen at the TFTR EZB site monitoring stations. The shielding installed for the PBX-M machine has kept the total dose equivalents* in occupied areas below occupational-exposure guidelines. Skyshine radiation from the neutron production by PBX-M added less than 1 mrem (0.01 mSv) in CY89 to the D-site environs [Gi90].

It is stated Laboratory policy that when occupational exposures have the potential to exceed 1000 mrem/y (10 mSv/y), the appropriate project manager must petition the PPPL Executive Safety Board (ESB) for an exemption. In addition, the Laboratory applies the DOE ALARA (As Low As Reasonably Achievable) policy to all its operations. This philosophy for control of occupational exposure means that environmental radiation levels, as a result of experimental device operation, are also very low and acceptable. To illustrate this point, a 1000 mrem dose equivalent from direct radiation at the outer TFTR test cell wall will result in less than 10 mrem at the EZB.

The design objective for TFTR is to stay below 10 mrem/y (0.1 mSv/y) above natural

*In all cases used in this report, the whole body is the critical organ and the term dose equivalent can be considered to be synonymous with the term effective dose equivalent.

background from all sources of radiation at the EZB. The TFTR, like other tokamaks, produces bremsstrahlung radiation from the electrons striking internal hardware at the end of a pulse. These X-rays, in the range of 0 to 20 MeV, also produce photoneutrons.

Injection of deuterium neutral beams began at the end of CY84. With these D-D runs, the neutron fluxes have increased each year as the neutral-beam heating power has increased. In CY85, the neutron production was on the order of 5×10^{16} for the entire year. This number increased to 2.4×10^{18} in CY86, to 3×10^{18} during a short run year in CY87, and to 9.04×10^{18} in CY88, and because of limited operation (also more plasma transport experiments and less supershots), the number reduced to 6.4×10^{18} in CY89. Additional shielding was added to the TFTR test cell walls in the middle of CY85. This added shielding has prevented the addition of any significant penetrating radiation to the environs due to TFTR operation. Radiation levels (mR) were recorded for some pulses outside the test cell, with the total dose equivalent at the TFTR EZB being less than 1 mrem (0.01 mSv) for CY89 [Gi90].

The TFTR real-time site boundary monitors are Reuter-Stokes Senti 1011 pressurized ionization chambers and ^3He -moderated neutron detectors. The electronics in the ionization chambers were modified to allow the integration of any prompt radiation resulting from a TFTR machine pulse which may be above natural background. These data are stored and processed using the Central Instrumentation, Control, and Data Acquisition (CICADA) computer system. Four of these monitoring stations are placed at the EZB (see Fig. 20). An additional eight ionization chambers of lower sensitivity, paired with neutron monitors, are located nearer the TFTR device (four outside the test cell wall, three in the basement, and one on the roof). These eight detector locations are for personnel safety and are not considered environmental detectors *per se*. However, data collected from them are used to help correlate the environmental measurements. Besides the moderated ^3He and fission neutron detectors, Bonner-type-moderated $\text{LiI}(\text{Eu})$ detectors were also used for monitoring neutron dose equivalents at various locations throughout the TFTR facility.

3.1.2 Special Surveys

In August 1980, EG&G Idaho, Inc., under DOE contract, conducted an aerial radiological survey of PPPL and surrounding areas [St81]. The detection system consisted of 20 sodium iodide detectors, a multichannel analyzer, and a magnetic tape recording system. The nominal gamma-ray exposure rate range observed was 8 to 10 mR/h. Detected radioisotopes

were consistent with normal background emitters. Since conditions have not changed at C- or D-sites since 1980, there is no need at this time to repeat the survey.

Other special surveys included a groundwater study by the U.S. Geological Survey (USGS) which began in 1985 and was completed in 1987 [Le87]. Figure 22 shows the potentiometric surface of the bedrock aquifer from this report. The report also indicated that the sumps under the TFTR complex create a cone of depression (Fig. 23). The USGS also presented PPPL some data developed in an unrelated study on naturally occurring radioactivity in the ground. Uranium-enriched rocks can be a source of radioactivity in groundwater [Sz87, Za87].

A comprehensive environmental survey was conducted by DOE/HQ utilizing outside subcontractors during the month of June 1988. This survey was a part of a DOE program which looked at 45 of their facilities. No significant environmental impact findings were noted at PPPL during this survey. A plan of action for findings was forwarded to DOE [St88e], and except for long-lead time items, the findings have been closed out. Soil sampling for petroleum hydrocarbons from former spills and for chromium in soils from previous use in cooling towers was accomplished in November 1988 [DOE88a]; however, results have not been received.

The Air Resources Laboratories Field Research Division (ARLFRD) of the National Oceanic and Atmospheric Administration (NOAA), Idaho Falls, Idaho, conducted atmospheric dispersion studies using tracer gases from July through September 1988. This group specializes in air quality by doing research on the physics of the lower atmosphere with emphasis on the processes contributing to atmospheric transport, dispersion, and deposition and on the development of numerical models using the results of this research. This study will be used to understand and predict human influence on the environment, especially with regard to the atmospheric transport and diffusion of toxic effluents [St89a].

While Nuclear Regulatory Commission (NRC) standard approved gaussian models, normally used to calculate atmospheric diffusion to support radiological dose assessments, are appropriate for sites in open terrain, they underestimate atmospheric dilution for sites like PPPL where potential sources of release are located in the midst of a complex of buildings. These buildings generate mechanical turbulence which increases atmospheric dilution and reduces dose. The field tests conducted by NOAA were performed to obtain a more realistic empirical description of actual atmospheric diffusion at PPPL in relation to TFTR and the

future Compact Ignition Tokamak (CIT). The results indicate a factor of 16 less potential dose equivalent than that calculated by using NRC gaussian models.

The Safety Office initiated and provided technical direction for a contract with Lawrence Livermore National Laboratory (LLNL) to perform a seismic hazard analysis for the PPPL site. This study, which was based on the latest methodology accepted by the Nuclear Regulatory Commission (NRC) for seismic analysis of Eastern U.S. nuclear power plants, indicated that the earthquake parameters applied to the TFTR project met and exceeded the current applicable DOE requirements [Sa89].

3.1.3 Airborne Radioactivity

Radioactivation of air and the release of tritium in measurable concentrations are not expected until TFTR D-T operations. A silica gel environmental tritium monitor was tested in 1986 and was placed in operation during the summer of 1987. With experience gained in a Canadian release modeling experiment and in the field, the monitor is now using molecular sieve in place of silica gel [Gr88b]. Based on D-D neutron production during CY89, it is estimated that a maximum of approximately 310 mCi (11.4 GBq) of tritium could have been added to the environs outside the TFTR facility. While detectable with the PPPL Differential Atmospheric Tritium Sampler (DATS), its release through a vacuum line made it technically hard to give a quantitative number. Our actual experience with the absorption and adsorption of tritium in TFTR vessel-graphite tiles in 1987 indicates that most of the tritium produced over the last few years by D-D reactions has been retained in the tiles [St88b]. The projected dose at the site boundary from 310 mCi is less than 1.0 μ rem (10 nSv) based on the use of NOAA χ/Q (see Table 40). While this is insignificant, a technical solution to actual measurements should be in place by the summer of 1990. An off-site monitor has shown some variation in background ambient levels which are not attributable to PPPL operations. Measurements at the TFTR fence line have shown ambient levels in the range of 1 to 5 pCi/m³ of elemental and oxide tritium concentrations. These measurements were made with the DATS [Gr88b].

Argon-41 is another potential air activation product from D-D reactions. Its maximum production in 1989 was 0.53 Ci with an estimated dose equivalent at the site boundary of 2×10^{-3} mrem (see Table 40).

In November 1983, a three-level, 60 meter tower was installed for gathering meteorological data. Five years' worth of data have now been collected. The wind-rose data for the first six years of tower operation are shown in Figs. 3 and 4. Analysis indicates that the site is dominated by neutral to moderately stable conditions, with moderately unstable to extremely unstable conditions occurring less than a few percent of the time. Average surface winds are about 2.1 m/s and rise to about 4.1 m/s at 60 m [Ko86a]. Based on data from this tower and NOAA tracer gas release-modeling, χ/Q values will be recalculated for the updated TFTR FSAR before D-T operations. The data were also checked for consistency by the Idaho National Engineering Laboratory (INEL) in their preparation of an Environmental Assessment (EA) for the CIT project. Data collection at 10 m will be added in 1990.

3.1.4 Waterborne Radioactivity

3.1.4.1 Surface Water

Surface water samples at eight locations (four on-site and four off-site) have been analyzed for tritium and photon emitters. Five of these locations have been monitored since CY82. Downstream sampling occurs after the mixing of effluent and ambient water is complete. Locations are indicated on Figs. 20 and 21.

Sample analysis has shown no unusual background radionuclides. Tritium analysis by liquid scintillation methods has shown tritium values to be less than 100 pCi/liter (3.7 Bq/liter) on all samples analyzed to date. Tritium enrichment procedures are used on some samples to detect lower levels. Rain water samples collected and analyzed ranged from less than 7 to 90 pCi/liter (see Table 37 and Fig. 25), which was similar to the 1985 range of 45 to 160 pCi/liter, the 1986 range of 40 to 140 pCi/liter, the 1987 range of 26 to 144 pCi/liter, and the 1988 range of 34 to 105 pCi/liter. The reason for this variation can be explained as follows: HT and HTO, mainly from prior world-wide, above-ground weapons tests, go into the stratosphere and are returned to the troposphere by turbulence. HT slowly converts to HTO. The residence time in the atmosphere is on the order of years. There is a variation of HTO in rain water as the stratosphere slowly turns over, with very little exchange between the stratosphere and troposphere in the winter months [Os88]. The peak values are slowly decreasing over the years which is consistent with the decay of tritium with no large inventories being added.

In 1988, PPPL initiated the collection of precipitation and monitored levels starting with the second quarter. While 1988 was a dry year, 1989 was a relatively wet year with over 55 inches (140 cm) of precipitation (See Fig. 24 and Table 36).

3.1.4.2 Groundwater

Two existing on-site wells, W4 and W5 on C-site (Fig. 20), were sampled (see Table 37). As a part of continuing efforts to characterize the site, a more comprehensive groundwater program was initiated in June 1985 through the U.S. Geological Survey. This program entailed the drilling of several monitoring wells on the TFTR site in order to help profile the groundwater system. The final survey report was issued in 1987 [Le87]. This report indicates a cone of depression created by the TFTR sump system (Fig. 23). The samples collected from two of the wells (W1 and W10 at D-site) were analyzed for tritium by PPPL. The sample results were consistent with previous testing accomplished by PPPL and the USGS and indicated tritium levels less than 100 pCi/liter (3.7 Bq/liter) (see Table 17). These values are consistent with surface-water measurements.

3.1.4.3 Drinking Water

Potable water is supplied by the public utility, Elizabethtown Water Co. In April 1984, a sampling point at the input to PPPL was established (E1 location, Fig. 20) to provide baseline data for water coming onto the site. Radiological analysis has included gamma spectroscopy and tritium-level determination. Tritium levels are similar to surface and well waters with measurements indicating less than 100 pCi/liter (3.7 Bq/liter); also, there are no unusual gamma-emitting radioisotopes. Radium and radon levels have not been measured.

3.1.5 Foodstuffs

Because there are so few dairy farms in this area, milk is not a viable analysis medium around the site. Also, the fish population is very scarce to nonexistent in Ditch 5 and Bee Brook, which carry the runoff from the site. The DOE agreed in 1986 that a substitute of vegetables and other biota from the surrounding area can be used for reference data. Sampling of various biota in 1989 indicated tritium levels below 100 pCi/liter (3.7 Bq/liter) [Gi90]. These levels are indicative of tritium in the environment.

3.1.6 Soil, Grass, and Vegetation

Off-site sampling locations were established in late 1985 (see Fig. 27). Soil and grass samples collected on-site and off-site in 1989 indicated tritium levels below 100 pCi/liter (3.7 Bq/liter) [see Fig. 26 and Table 38]. Laboratory techniques for doing these analyses were perfected in CY84 [Gr85], and the techniques are documented in the Radiological Environmental Monitoring Laboratory Handbook [REML86]. These baselines are being established since surface soils and vegetation are among the best indicators of the presence of tritium after a release [Jo74], [Mu77], [Mu82]. The present detected levels are indicative of tritium in the environment.

3.2 Nonradioactive Pollutants

3.2.1 Airborne Effluents [Ki90]

The PPPL has a New Jersey Department of Environmental Protection (NJDEP) permit for its five C-site boilers and two fuel tank vents. The seven permit certificates, numbered 061294 through 061300, were renewed in 1987 and will next expire on March 31, 1992. New air permits applied for and received include the CAS building degreaser, the Field Coil and Power Conversion (FCPC) building degreaser, the TFTR emergency generator diesel engine, an 8,000 gallon unleaded gasoline tank vent (#E2), and a 15,000 gallon diesel tank vent (E#8).

Measurements of actual boiler emissions are not required. Emissions were initially calculated using formulas supplied by the NJDEP [Ki88]. These formulas are based solely on the percent sulfur and the number of gallons of oil burned per hour in each boiler. In the last quarter of CY87, PPPL purchased a combustion-efficiency analyzer. This device indicates boiler efficiency, oxygen content, flue-gas temperature, and carbon-dioxide content of the stack gas for both oil and natural-gas fuels. This information is recorded and entered into a log book by the boiler operators.

3.2.2 Water Utilization [Ki90]

3.2.2.1 Drinking Water

Potable water is supplied by the public utility, Elizabethtown Water Co. The PPPL used

approximately 21.5 million gallons in CY89. This is a significant reduction from years prior to 1987 because of the changeover to Delaware & Raritan (D&R) Canal water for the cooling-water systems. Water quality analysis at the input to PPPL was initiated in CY84 to measure nonradioactive pollutants (Table 23, E-1 location), as well as to measure potential radioactive pollutants exclusive of radium or radon.

3.2.2.2 Process (nonpotable) Water

Nonpotable water is pumped by PPPL from the D&R Canal as authorized by a permit agreement with the New Jersey Water Supply Authority. The present agreement gives PPPL the right to draw up to one million gallons of water per day for process and fire-fighting purposes for the period beginning July 1984 and ending on September 30, 1991. Renewal is expected at the end of the present contract. Filtration to remove suspended solids is the primary treatment. In 1986, a multimedia sand filter was installed to allow the source of the D-site cooling tower make-up water to be changed from potable water to process-water supply. PPPL used approximately 64.5 million gallons of canal water during CY89. The sampling point (C-1) was established to provide baseline data for process water coming on-site. Table 20 indicates results of water quality analysis at the canal.

3.2.2.3 Storm Sewage

Storm sewage, which includes cooling tower and boiler blowdown, is discharged into surface waters and is governed at C- and D-sites by National Pollutant Discharge Elimination System (NPDES) Permit No. NJ0023922 (effective date November 1, 1984 - expiration date October 31, 1989. This permit is still in effect while NJDEP reviews the new application request). All process water and most runoff water from C- and D-sites now pass through a detention basin. Upgrades to the detention basin, including an oil-spill detection and alarm system, were completed in 1986. As a result of minor problems following the transformer-oil leak in 1988 [St88f], another analysis of this system determined that the best long-term environmental solution is to line the detention basin and to find more reliable oil sensors. Quarterly water-chemistry reports, compiled from the data of Table 22, were submitted to the State of New Jersey in 1989 in accordance with NJDEP requirements. PPPL was well within the allowable limits for all testing parameters during CY89.

Cooling-water treatment was changed from a chromate-based corrosion inhibitor to a nonchromate inhibitor in June 1983. Water analyses downstream and groundwater tests (see

Tables 17-33) have not indicated concentrations of any environmental pollutants, in general, above applicable codes, regulations, or standards. Two shallow wells (D11 and D12), next to the detention basin, have shown some lead. While investigations are still going on, it is believed that the lead came from overspray during a transformer maintenance painting task. As a result of the initial improvements made to the detention basin in 1986, the NJDEP required an application for discharge to groundwater. After the application for this permit was filed in 1986, the NJDEP proposed the addition of monitoring wells around the detention basin. While DOE has requested a hearing on some aspects of the permit requirements, PPPL came into compliance with the existing permit requirements in November 1989.

An updated Spill Prevention Control and Countermeasures (SPCC) Plan was received from an environmental consultant in January 1985 and currently scheduled for an upgrade completion in CY90. The final update was delayed until after the EPA issued the Final Regulations for Underground Storage Tanks (UST). With the experience of the underground storage tank leakage, PPPL will eliminate most of its underground tanks within the next year. While the SPCC response team meets quarterly for training sessions to improve their response efficiency in case a spill is detected, the Laboratory's first response capabilities lie with the HAZMAT team of the Emergency Services Unit (ESU).

3.2.2.4 Sanitary Sewage

Sanitary sewage is discharged to the publicly owned treatment works operated by South Brunswick Township at the Stony Brook Regional Authority. Flow rates are measured by the PPPL sanitary sewage metering station and indicated a total volume discharge of approximately 27.2 million gallons in CY89. Sampling of PPPL discharges, performed by the publicly owned treatment works, has determined that pretreatment is unnecessary. Therefore, PPPL is in compliance with the EPA Pretreatment Standard, 40 CFR Part 403.

3.2.2.5 Groundwater

Monitoring of groundwater was accomplished by using former production wells, W4 and W5 (see Table 27 and 28), and wells TW#1 and TW#10 established by the USGS to study groundwater flow characteristics (see Tables 29 and 30). USGS results from TW#1 and TW#10 (see Table 17) indicated some trace chemicals (e.g., tetrachloroethylene). Other monitoring data for these two wells are listed in Tables 29 and 30.

A program has been proposed to further define groundwater flow patterns so that a determination can be made on whether the trace contamination in TW#1 and TW#10 is due to on-site activities or is a function of activities beyond our site boundaries. As part of our NJPDES permit, groundwater sampling was begun at the end of 1989 on seven additional wells. The permit number is the same as the surface water, NJ0023922, with an effective date of May 1, 1989, and an expiration date of May 1, 1994. Data, which includes volatile organics for five wells, are listed in Tables 31 and 32. Potential programs in CY90 may include soil gas testing to find the source of these contaminations.

3.2.2.6 Surface Water

Surface water is monitored for potential nonradioactive pollutants both on-site and at surface water discharge pathways (upstream and downstream) off-site (See Figs. 20-21 and Tables 18-26).

3.2.3 Spills

Several oil spills were recorded in CY89. Those which posed a potential threat to the environment were reported to the NJDEP in accordance with their reporting requirements. Approximately 5 quarts of motor oil were dumped down a pipe for a water access valve [St89b]. An acid spill within a building had no potential impacts to the environment [St89c]. Approximately 22 pounds of chlorine gas was released in an effort to change over to a less hazardous liquid chlorine water treatment procedure [St89d]. In 1988, an overflow of an underground fuel-oil tank occurred during a fill procedure [St88c]. The cleanup of this incident has expanded into removal of underground tanks and chronic leaks from fill procedures and tank and piping leaks over a 30 year period. All oil spills are responded to immediately by in-house HAZMAT personnel, and subcontractors are utilized to aid in clean-up if required. Because of the prompt internal response and vigilance by employees, the 1989 spills resulted in no impact to the environment [St89b, St89c, St89d].

3.2.4 Herbicides, Fertilizer, and Pesticides [Ra90]

During CY89, the use of herbicides, pesticides, and fertilizers, which was formerly done by Princeton University buildings and grounds maintenance personnel, was taken over by PPPL utilizing an outside contractor. These materials are applied in accordance with state and

federal regulations. Herbicides are applied by a certified applicator. Table 34 lists the quantities applied during CY89.

3.2.5 Polychlorinated Biphenyls (PCBs)

Beginning in CY82, PPPL started a program to dispose of PCB containing capacitors, transformers, and other similarly contaminated items. During the early phases of the program, all stored items in a GSA (General Services Administration) Warehouse in Belle Mead, NJ, were discarded through approved disposal contractors. Remaining PCB items were labeled, as required by EPA regulations, and an inventory, inspection, and status report program was initiated. A Hazardous Material Coordinator was appointed to ensure that any newly identified leaking capacitors or transformers would be dispositioned promptly and properly. At the beginning of CY84, PPPL still had 15 PCB transformers and 6,005 large capacitors containing PCBs. In CY84, 375 large and 54 small PCB capacitors were disposed of as well as the oil and containers of two transformers. In 1985, an additional 1,330 large capacitors and 22 small capacitors were removed properly from the site. In 1986, a few small capacitors but no transformers were discarded. In 1987, two transformers containing 700 gallons of PCB fluid were disposed of. In addition, 1,145 gallons of less than 500 ppm PCB fluid were generated from rework/classification of six PCB transformers to non-PCB transformers, and 391 capacitors were disposed of. PCB capacitors are being disposed of as they are taken out of service. In 1988, 1,769 capacitors and four small transformers were removed. PCB material disposal volume amounted to 172,465 pounds of solids and 45 gallons of liquid. Transformer replacement has been initiated and is scheduled to meet the EPA requirements. A testing of all remaining transformers in 1989 indicated several other transformers on-site either contained PCB oil or were PCB contaminated. Eight transformers were removed in 1989. All remaining PCB transformers will be removed or retrofilled in 1990.

3.2.6 Hazardous Wastes

Responsibility for this program rests with the PPPL Hazardous Material Coordinator under the Materiel Control Office. A facility was set up in CY82 for temporary storage of hazardous materials. A new area was built in 1986. This facility has concrete floors with containment walls, fire alarms, security surveillance, fire extinguishers, an eye-wash station, an emergency shower, and telephones. Improvements to the facility, following experience gained from operational needs, were made in CY88.

The Hazardous Waste Generator Annual Report (EPA ID number NJ1960011152) has been submitted for 1989 in accordance with EPA requirements [La90]. During 1989, 634,303 pounds of solid materials and 49,620 gallons of liquid waste were disposed of at EPA-certified treatment, storage, and disposal facilities. These totals included 185,908 pounds of PCBs (oil plus containers). These numbers reflect actual waste, plus containers and packing materials. It should be noted that a significant fraction of the waste was oil-contaminated soil from oil-spill cleanup.

3.3 Environmental Impact

3.3.1 Assessment of Radiation Dose to the Public

PPPL is located in one of the less densely populated, but also one of the fastest growth areas in the metropolitan region between New York City and Philadelphia. Census data indicate that approximately 16 million people live within 80 km (50 miles) of the site and approximately 212,000 within 16 km (10 miles) of PPPL. The detailed distribution of population as a function of distance is given in Tables 4-16. Because of ever-increasing commercial growth in this area, a demographic update was planned for TFTR but was completed as a requirement for the CIT Environmental Assessment [Be87a].

The overall integrated exposure-dose equivalent from all sources (excluding natural background), to a hypothetical individual residing at the PPPL site boundary 24 h/day, 365 days/y, was estimated to be less than 1 mrem (0.01 mSv) for CY89 [Gi90]. Detailed person-rem calculations for the surrounding population were not performed, because the value would be insignificant in comparison to the approximately 100 mrem (1 mSv) each individual receives from the natural background, exclusive of radon, in New Jersey. However, scaling to calculated data was done and indicates a value of only 1.3×10^{-2} person-rem out to 80 km (see Table 40).

3.3.2 Assessment of Nonradioactive Pollutants

There were no activities during CY89 that created problems with respect to nonradioactive pollutants. The chronic oil spill from underground tanks presents some potential minor environmental impacts which are being addressed.

Polychlorinated biphenyls (PCB's) and other toxic materials continue to be disposed of in accordance with EPA requirements. Herbicides, pesticides, and fertilizers were used in very limited quantities.

3.4 Environmental Compliance Self-Assessments

3.4.1 Compliance Summary

PPPL is in compliance with all applicable state, federal, and local environmental regulations. The status of each applicable environmental statute is listed below:

- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

PPPL is not involved with CERCLA mandated cleanups or compliance activities. CERCLA is only invoked under the requirements for SARA Title III for which PPPL is in compliance.

- Clean Air Act (CAA)

PPPL was in compliance with the requirements of the CAA in 1989. PPPL is adding a stack sampler for tritium releases to the TFTR facility to meet new requirements by the EPA. Current releases produce insignificant dose to any individual.

- Clean Water Act (CWA)

PPPL is in compliance with all requirement of the CWA. Lead levels noted in two groundwater wells is being assessed.

- Resource Conservation and Recovery Act (RCRA)

The Laboratory is in compliance with all terms and conditions required of a hazardous waste generator. PPPL is also in compliance with all requirements of the RCRA mandated Underground Storage Tank program.

3.4.2. Current Issues and Actions

The sole ongoing environmental compliance issues is the request for an adjudicatory hearing,

by DOE, under the current NJPDES discharge to groundwater permit. DOE is contesting the permit requirement that monitoring wells, with a monitoring program, be placed off-site on Princeton University property, at PPPL expense, when the University volunteered to cover these requirements. The DOE is awaiting a hearing date and is in compliance with all permit mandated activities. PPPL has not been visited by a Tiger Team.

3.4.3. Environmental Permits

Environmental permits maintained by PPPL are listed in Table 39. A discussion of the Environmental permits, by the applicable statutes, is listed below :

- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

PPPL is not involved with CERCLA mandated cleanups or compliance activities.

- Clean Air Act (CAA)

PPPL is in compliance with all requirements of the CAA. The Laboratory maintains permits for 5 boiler vent stacks, 2 fuel oil storage tank vents, 1 gasoline tank vent, 1 diesel tank vent, 2 degreaser vents, and 2 emergency diesel generator exhaust stacks. All permits for these emissions are current, and all equipment under permit is operated within the permit specifications. PPPL recently removed one of the five boilers operated on site and has not yet terminated the stack permit for the fifth boiler. Four underground storage tanks also will be removed from the Laboratory in 1990, and permits for the vent pipes for the gasoline tank, diesel tank and one of the two fuel oil vent permits must be terminated. Maintenance of permits for equipment which has been removed is not a violation of the CAA. Termination of air permits for the removed sources will be accomplished as soon as practicable.

- Clean Water Act (CWA)

PPPL is in compliance with all requirements of the CWA. The Laboratory maintains two permits under the New Jersey Pollution Discharge Elimination System (NJPDES) for discharges to surface water and groundwater. The permits are for a detention basin which discharges to Bee Brook and for non-point source infiltration of the detention basin waters to groundwater. An adjudicatory hearing is planned for the groundwater permit where several of the permit conditions will be contested. In the interim, however, the permit is being

maintained in full compliance including those conditions being contested in the upcoming hearing.

- Resource Conservation and Recovery Act (RCRA)

PPPL maintains EPA Number (NJ1960011152) for RCRA generator status. The Laboratory is in compliance with all terms and conditions required of a "generator" status.

PPPL maintains and is in compliance with permits for 4 USTs in operation on the site. The permit will be modified to reflect the 1990 removal of 4 operational tanks and 1 abandoned UST removed during remediation activities. Note that the underground storage tank (UST) program is a part of RCRA compliance activities.

- Miscellaneous Permits

PPPL maintains permits for medical waste generation as required by the NJDEP and for the purchase of potable water from the Elizabethtown Water Company. PPPL is in compliance with all terms and conditions of these permits.

4.0 QUALITY ASSURANCE FOR LABORATORY ANALYSIS

Analysis of water samples for radioactivity was accomplished in-house. In general, in-house procedures follow the HASL-300 Manual [Vo82]. In-house procedures adopt accepted techniques and are documented in the Radiological Environmental Monitoring Laboratory (REML) manual [REML86]. PPPL participates in the EPA (Las Vegas) program and has reinitiated its analyses of samples provided by the DOE Environmental Measurements Laboratory (EML) in New York City. These programs provide blind samples for analysis and subsequent comparison to values obtained by other participants, as well as to known values. Results are shown in Table 35.

In CY84, PPPL initiated a program to have its radiation-counting laboratory certified by the State of New Jersey through the EPA Quality Assurance (QA) program. In March 1986, the REML facilities and procedures were reviewed and inspected by EPA/Las Vegas and the NJDEP. The laboratory was certified for tritium analysis in urine and water and recertified in these areas in 1988 and again in 1989. This certification is expected to be extended to gamma

spectroscopy in 1990 as all of the blind samples to date have been within expected detection limits.

The vendor used for nonradioactive water quality analysis participates in a State of New Jersey QA program and has a quality assurance plan [A185]. A blind split-sample was also sent for analysis (Table 33).

5.0 FUTURE PROGRAM EXPANSION

5.1 Meteorological

A meteorological tower was installed in November 1983. Data from this system are being used in updating dose calculations for the updated version of the TFTR FSAR. Data were also evaluated by the CIT project in relation to siting the CIT at PPPL. Several dose-assessment codes are being employed by PPPL to utilize the data from this tower in the calculation of projected doses. These codes include the required DOE standard AIRDOS-EPA, as well as PAVAN, XOQDOQ, and an Ontario Hydro version of TRITMOD. Future plans include considerations of hooking up a real-time output of the meteorological data. These plans have been put on hold with recent budget cuts. Instrumentation will be added at 10 m in 1990 to collect wind speed and direction in addition to the present instruments at 30 and 60 m.

5.2 Water Quality

The initial phases of a groundwater monitoring program began in CY85. Analysis of water samples from two D-site wells was added to the monitoring program in CY86 utilizing USGS data. PPPL took over the water quality program on these two wells in December 1987. New wells were to be added in response to new state requirements for a groundwater discharge permit. In addition, an expanded groundwater program is being planned to more fully understand our regional groundwater flow, surrounding area (off-site) groundwater contamination, and in anticipation of requirements for CIT.

5.3 Radioactive Effluents

5.3.1 Air, Gaseous and Particulates

Based on collected data, a decision was made in CY84 to limit the specific air and particulate real-time monitors at the EZB to a beta detector only. Environmental tritium monitors tested in CY86 were deployed at the EZB in CY87. These were to be extended to off-site locations in CY88 but were delayed because of budget reductions at the end of the year. A baseline station was established off-site during 1989.

5.3.2 Off-Site Radiological Monitoring

An off-site grab sample water-analysis program is well established. Whether more sampling points will be added in the future depends on reevaluation of the program, which is done annually. Locations for off-site tritium and particulate monitoring stations were negotiated in CY86. The placement of hardware at these sites was expected to be finished in CY88 but has been extended into CY90. Soil and vegetation sampling is under way and will continue.

5.4 Nonradioactive Effluents

Air-effluent standards will continue to be met by following the guidelines of the NJDEP. Any potential toxic materials will be monitored and disposed of in accordance with applicable regulations and accepted guidelines. With respect to the detention basin, application has been made for a groundwater discharge permit. Also, because of the addition of an oil separator on the detention basin, the NJDEP had requested that we apply for a treatment works permit. A permit application was made, and a subsequent waiver was granted for the treatment works permit [Ku86].

6.0 REGULATIONS AND SAFETY CRITERIA

The appropriate Radiation Protection Standard for penetrating radiation was taken from DOE Order 5480.1A, Chapter XI. Specific criteria for implementing these standards on TFTR are contained in TFTR Operational Safety Requirements, in particular, OSR/TFTR/0-2F-C. The concentration guides, used in the analyses of surface water samples for radioactivity, were taken from DOE Order 5480.1A, Chapter XI, Table II, Column 2 (Water in Uncontrolled

Areas). The concentration guides for airborne activity are taken from the same DOE Order, Table I, Column 1 (Concentration in Air in Uncontrolled Areas). Tritium, for example, is listed as 2×10^{-7} mCi/mliter. The Laboratory was also in compliance with the new DOE Order 5480.11 [DOE88b], and with interim requirements on dose equivalent to the public established by a DOE letter [Mi85].

Air and Water Pollution Standards for nonradioactive pollutants were taken from the New Jersey Administrative Code (NJAC), Department of Environmental Protection 7:1-1, *et seq* and 7:27-1, *et seq*. The appropriate regulations for PCBs and hazardous waste are found in the U.S. Code of Federal Regulations, 40 CFR 761 and 40 CFR 260-265, respectively.

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8.0 REFERENCES

- Al85 Alinea, E. A., 1985, Princeton Testing Laboratory Quality Control Manual, Princeton Testing Laboratory, Princeton, NJ.
- Be87a Bentz, L. K., and Bender, D. S., 1987, "Population Projections, 0-50 Mile Radius from the CIT Facility: Supplementary Documentation for an Environmental Assessment for the CIT at PPPL," EGG-EP-7751, INEL, Idaho Falls, Idaho.
- Be87b Bentz, L. K., and Bender, D. S., 1987, "Socioeconomic Information, Plainsboro Area, New Jersey: Supplementary Documentation for an Environmental Assessment for the CIT at PPPL," EGG-EP-7752, INEL, Idaho Falls, Idaho.
- Co81 Corley, J. P. et al., 1982, A Guide for Environmental Radiological Surveillance at U.S. Department of Energy Installations DOE/EP-023, (National Technical Information Service).
- DOE81 DOE Order 5480.1, Ch. XI, 8/13/81, Environmental Protection, Safety and Health Protection Program for DOE Operations, U.S. Department of Energy, Operational and Environmental Safety Division.
- DOE88a Environmental Survey Sampling and Analysis Plan, November 1988, PPPL S&A Plan, INEL/EG&G report to DOE.
- DOE88b DOE Order 5480.11, 7/20/89, Radiation Protection for Occupational Workers.
- En87 Envirosphere Company, 1987, "Ecological Survey of Compact Ignition Tokamak Site and Surroundings at Princeton University's Forrestal Campus," Envirosphere Company, Division of Ebasco, Report to INEL for the CIT.
- Fl84 Fleming, R. B. et al, February 1984, Safety Assessment Document for the Princeton Beta Experiment, Princeton Plasma Physics Laboratory (unpublished).
- FSAR82 Final Safety Analysis Report, Tokamak Fusion Test Reactor Facilities, Princeton Plasmas Physics Laboratory, 1982.
- Gi90 Gilbert, J., April 1990, "PPPL Ionizing Radiation Report for Calendar Year 1989," JG-135, Princeton Plasma Physics Laboratory Internal Report.
- Gr85 Griesbach, O. A., and Stencel, J. R., "An Environmental Monitoring Program for a Fusion Test Reactor," Proceedings of the 18th Midyear Topical Meeting of the Health Physics Society, Colorado Springs, CO, Jan. 6-10, 1985, pp. 227-233.
- Gr88a Griesbach, O. A, and Stencel, J. R., "Operational Experience with the DATS Sampler During the Canadian Tritium Modeling Experiment," Fusion Technology, 14, Part 2A, Sept. 1988, 1199-1202.
- Gr88b Griesbach, O. A., and Stencel, J. R., "The PPPL Differential Atmospheric Tritium System (DATS)," 22nd Midyear Topical Meeting of the Health Physics Society, San Antonio, TX, Dec.4-8, 1988, pp. 374-380.
- He88 Hendel, H., 1988, personal communication.

- He89 Hendel, H, 1989, personal communication.
- Ja90 Jassby, D., 1990, personal communication.
- Jo74 Jordan, C. F., Stewart, M., and Kline, J., 1974, "Tritium Movement in Soils: The Importance of Exchange and High Initial Dispersion," Health Physics, 27, 37-43.
- Ki88 Kircher, C., 3/14/88, "Calculations for Boiler Emissions," Princeton Plasma Physics Laboratory, Internal Memo.
- Ki90 Kircher, C., 3/6/90, "Annual Environmental Report for CY89," Princeton Plasma Physics Laboratory, Internal Memo.
- Ko86a Kolibal, J., *et al*, 1986, Meteorological Data Summaries for the TFTR from January 1984 to December 1985, Princeton Plasma Physics Laboratory Report No. PPPL-2369.
- Ko86b Kolibal, J., 3/24/86, "Sectorized Agricultural and Population Data Estimates," EAD-1442, Plasma Physics Laboratory Internal Memo.
- Ku86 Kurisko, P. C., 12/5/86, "Treatment Works Approval Waiver NJPDES No. NJ0023922," NJDEP letter to H. Mix, DOE/PAO.
- Ku89 Ku, Long-poe, 4/18/89, "Wind Roses 1984-89," EAD-3389, Plasma Physics Laboratory Internal Memo.
- La90 Larson, S. B., 2/14/90, "Annual Hazardous Waste Generators Report for CY89"
- Le87 Lewis, J. C. and Spitz, F. J., 1987, "Hydrogeology, Ground-Water Quality, and The Possible Effects of a Hypothetical Radioactive-Water Spill, Plainsboro Township, New Jersey," U.S. Geological Survey Water-Resources Investigations Report 87-4092, West Trenton, NJ.
- Mc83 McCarthy, E. F., and Errera, L. J., 8/15/83, Final Monitoring Plan: Tokamak Fusion Test Reactor Meteorological Monitoring Program, TRC Consultants, Inc., 800 Connecticut Blvd., East Hartford, CT 06108.
- Mc89 McKenzie-Carter, M. A. and Lyon, R. E., "Methodology for Assessing the Radiological Consequences of Radioactive Releases from the CIT Facility at PPPL," EGG-ESE-8600, Idaho National Engineering Laboratory (INEL) Informal Report (August 1989) 73 pp.
- Mi85 Mix, H. C., Nov. 85, "Radiation Standard for Protection of the Public in the Vicinity of the Department of Energy (DOE) Facilities," DOE/PAO letter to PPPL.
- Mu77 Murphy, C. E., Jr., Watts, J. R., and Corey, J. C., 1977, "Environmental Tritium Transport from Atmospheric Release of Molecular Tritium," Health Physics, 33, 325-331.
- Mu82 Murphy, C. E., Jr., Sweet, C. W., and Fallon, R. D., 1982, "Tritium Transport Around Nuclear Facilities," Nuclear Safety, 23, 667-685.
- Os88 Ostlund, G., University of Miami, private communication, November 1988.

- PSAR78 Preliminary Safety Analysis Report, Princeton Plasma Physics Laboratory Tokamak Fusion Test Reactor, 1978.
- Ra90 Rabiger, E., 2/28/90, "1989 Grounds Treatment," Princeton Plasma Physics Laboratory internal memo.
- REML86 Radiological Environmental Monitoring Laboratory Manual, Princeton Plasma Physics Laboratory, 1986.
- Sa89 Savy, J. B., "Princeton Plasma Physics Laboratory (PPPL) Seismic Hazard Analysis," UCID Report-21829 (October 1989) 138 pp.
- St81 Steiner, P. A., 1981, An Aerial Radiological Survey of the Princeton Plasma Physics Laboratory and Surrounding Area, U.S. DOE Remote Sensing Laboratory Report, EGG-1182-1806, UC-41.
- St82 Strenge, D. L., Kennedy, W. E., Jr, and Corley, J. P., 1982, Environmental Dose Assessment Methods for Normal Operations of DOE Nuclear Sites, PNL-4410/UC-11.
- St88a Stencel, J. R. and Parsells, R. F., Editors, April 1988, Safety Assessment Document (SAD) for the Princeton Beta Experiment Modification (PBX-M), Princeton Plasma Physics Laboratory Report PPPL-2496.
- St88b Stencel, J. R., Gilbert, J. D., Griesbach, O. A., and Greco, J. M., "TFTR Health Physics Tritium Measurements Following D-D Operations," *Fusion Technology*, 14, Part 2A; 1047-1053; Sept. 1988.
- St88c Stencel, J. R., 1988, "Environmental Protection Spill Cleanup Report EP88-03, PM&E Fuel Oil Tank Overflow, August 10, 1988," DEP ID# 88-08-10-1148, Internal PPPL Environmental Committee Report.
- St88d Stencel, J. R., May 1988, Environmental Monitoring Report for Calendar Year 1987, Princeton Plasma Physics Laboratory Report PPPL-2496.
- St88e Stencel, J. R., 1988, "PPPL Environmental Survey Plan: A Response to the Findings of the June 1988 DOE/HQ Environmental Survey," JRS-1237, PPPL report to DOE.
- St88f Stencel, J. R., 1988, "Environmental Protection Spill Cleanup Report EP88-01, NB Transformer, January 19, 1988," DEP ID #88-01-19-1617, Internal PPPL Environmental Committee Report.
- St89a Start, G. E., Dickson, C. R., Sagendorf, J. F., Ackermann, G. R., Clawson, K. L., Johnson, R. C., and Hukari, N. F., "Atmospheric Diffusion for Airflows in the Vicinity of the James Forrestal Campus, Princeton University," Final Report, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Air Resources Laboratory Field Research Division, Idaho Falls, Idaho, Vol. 1 (May 1989) 84 pp, Vol. 2 (June 1989) 385 pp.
- St89b Stencel, J. R., 1989, "Environmental Protection Spill Cleanup Report EP89-01, Oil Dump in water Shutoff Valve Access Pipe, January 25, 1989," DEP ID #89-01-25-0935, Internal PPPL Environmental Committee Report.

- St89c Stencel, J. R., 1989, "Environmental Protection Spill Cleanup Report EP89-02, Acid Spill in the ESAT Building, August 23, 1989," Internal PPPL Environmental Committee Report.
- St89d Stencel, J. R., 1989, "Environmental Protection Spill Cleanup Report EP89-03, Canal Pump House Chlorine Air Release, September 12, 1989," DEP ID #89-09-12-1235, Internal PPPL Environmental Committee Report.
- Sz87 Szabo, Z. and Zapecza, O. S., "Relation Between Natural Radionuclide Activities and Chemical Constituents in Ground Water in the Newark Basin, New Jersey," Radon, Radium, and Other Radioactivity in Ground Water, Hydrogeologic Impact and Application to Indoor Airborne Contamination, Proceedings of the National Water Well Association Conference, April 7-9, 1987, Somerset, NJ, available from Lewis Publishers.
- Vo82 Volchok, H. L., and de Planque, G., 1982, EML Procedures Manual HASL 300, Department of Energy, Environmental Measurements Laboratory, 376 Hudson St., NY, NY 10014.
- Za87 Zapecza, O. S. and Szabo, Z., "Source and Distribution of Natural Radioactivity in Ground Water in the Newark Basin, New Jersey," Radon, Radium, and Other Radioactivity in Ground Water, Hydrogeologic Impact and Application to Indoor Airborne Contamination, Proceedings of the National Water Well Association Conference, April 7-9, 1987, Somerset, NJ, available from Lewis Publishers.

Table 1

TFTR Radiation Exposure Criteria

The research facility radiation exposure criteria itemized in this table shall be invoked for the TFTR only and shall not be construed as being applicable to subsequent fusion test facilities, research facilities, or reactor projects. The values quoted are for whole body exposures, however, the DOE manual requirements for other organs (hands, arms, bones, etc.) and other time periods (quarterly) are also applicable to TFTR and reductions between limits and design objective shall be consistent with those of the table.

Condition	Off-Site ≥ 125 m		On-Site < 125 m	
	Limit	Design Objective	Design Limit	Objective
Routine Operation mrem/yr [footnotes (a), (b), & (e)]	500 to an individual (e)	≤100 to an individual	500 in an uncontrolled area	≤ 100 in an uncontrolled area
	170 average population member (e)	≤ 35 average population member	5000 in a controlled area	≤ 1000 in a controlled area
Accident rem [footnotes (c)]	25	≤5 (d)	25	25

- (a) Routine operations consist of:
- 1) Normal component operation including shutdown, repair, maintenance, checkout, adjustment, etc.
 - 2) Operational occurrences such as leaks, loss of power, and component malfunctions that are likely to occur once or more during the life of the facility.
- (b) For normal operation, defined in (a) 1) above, the off-site design objective shall be 10 mrem/yr.
- (c) Accident conditions consist of:
- 1) Very low probability events such as "most intense predicted" phenomena.
 - 2) Low probability events such as "most probable" natural phenomena and other component failure events that are not likely to occur during the life of the facility.
- (d) For those accident conditions defined by (c) 1) above, the off-site design objective shall be 5 rem and that for (c) 2) above, 1 rem.
- (e) For emission of airborne radionuclides, the off-site limit on dose equivalent is 25 mrem/y to the whole body and 75 mrem/y to the critical organ. *This number will be 10 mrem/y effective dose equivalent in 1990. Also the 500 mrem/y will be changed to 100 mrem/y to reflect current regulations.*

Table 2. Critical Pathways

<u>Path I.D.</u>	<u>Discharge Pathway</u>		
A1	Atmospheric --->	Whole Body Exposure	
A2	Atmospheric --->	Inhalation Exposure	
A3	Atmospheric --->	Deposition on Soil & Vegetation, Ingestion, Whole Body Exposure	
L1	Liquid Water Way --->	Drinking Water Supply --> Man	
L2	Liquid Water Way --->	External Exposure	
L3	Liquid Water Way --->	Fish ---> Man	

Table 3. Monitoring Program Covering Critical Pathways

Type of Sample	Critical Path I.D.	Sample Point Description	Sampling Frequency	Analysis
Surface	L1,L2,L3 & A3	1) Cooling Water Discharge Drainage 2) Bee Brook Upstream & Downstream 3) D&R Canal	Monthly	Tritium and Gamma Spectroscopy
Soil & Sod	A3	Within 1 km radius		Tritium and Gamma Spectroscopy
Biota (Fruits & Vegetables)	A3	Within 3 km radius	Seasonal	Tritium & Gamma Spectroscopy
Surface Water	L1, L2	Liquid Effluent Collection Tanks	As Required by Filling	Tritium and Gamma Spectroscopy, Volume
Air	A1-A3	Test Cell	Continuous	Activated Air (Gross β) ^3H (HT and HTO)
Air	A1-A3	Vault	Continuous	^3H (HT and HTO)
Air	A1-A3	HVAC Discharge (Stack)	Continuous	Activated Air (Gross β) HT and HTO, Particulates, Volume
Direct & Air (on-site)		4 Locations at EZB on-site	Continuous	γ , n, ^3H (HT and HTO), Gross β for activated air & particulates with Gamma Spectroscopy, TLD
Direct & Air (off-site)		6 Locations off-site within 1 km radius	Continuous (integrated)	^3H (HT and HTO), TLD for air γ , Gamma Spec. for particulates

Table 4*

Population of Municipalities Within 0 - 10 Miles of PPPL

1985 - 2010

Municipality	1985 (1)	1995	2000	2005	2010	
Mercer County (Total) (2)	317,683	349,700	339,400	364,200	377,100	Mercer County (Total)
Mercer County (Part)	190,683	219,550	228,100	230,550	240,500	Mercer County (Part)
East Windsor Twp.	22,682	24,750	26,000	26,350	29,350	East Windsor Twp.
Hightstown B.	4,494	5,050	5,100	5,100	5,100	Hightstown B.
Hamilton Twp.	85,766	88,850	90,000	91,200	94,450	Hamilton Twp.
Hopewell Twp.	11,040	13,025	15,000	15,200	16,200	Hopewell Twp.
Hopewell B.	2,013	2,075	2,100	2,100	2,100	Hopewell B.
Pennington B.	2,232	2,300	2,300	2,350	2,400	Pennington B.
Lawrence Twp.	22,804	31,100	33,900	34,000	34,100	Lawrence Twp.
Princeton Twp.	14,202	14,550	14,700	14,900	15,400	Princeton Twp.
Princeton B.	12,031	12,650	12,700	12,700	12,700	Princeton B.
Washington Twp.	3,719	8,650	8,800	8,900	9,200	Washington Twp.
West Windsor Twp.	9,700	16,550	17,500	17,750	19,500	West Windsor Twp.
Middlesex County (Total) (2)	626,703	695,432	724,410	760,800	791,800	Middlesex County (Total)
Middlesex County (Part)	121,984	171,183	192,396	202,000	219,100	Middlesex County (Part)
Cranbury Twp.	2,145	5,695	8,033	8,450	8,800	Cranbury Twp.
East Brunswick Twp.	40,770	43,630	44,753	47,000	50,900	East Brunswick Twp.
Helmetta B.	973	965	949	950	950	Helmetta Twp.
Monroe Twp.	19,255	28,711	34,737	36,500	38,200	Monroe Twp.
Jamesburg B.	4,402	4,723	4,805	5,050	5,050	Jamesburg B.
North Brunswick Twp.	25,427	31,495	33,916	35,600	37,000	North Brunswick Twp.
Plainsboro Twp.	9,040	15,662	17,161	18,000	20,700	Plainsboro Twp.
South Brunswick Twp.	19,972	40,384	48,042	50,450	57,500	South Brunswick Twp.
Somerset County (Total) (2)	210,318	250,025	263,800	279,765	295,730	Somerset County (Total)
Somerset County (Part)	65,276	89,280	97,820	106,610	115,400	Somerset County (Part)
Franklin Twp.	33,952	47,945	52,790	57,790	62,790	Franklin Twp.
Hillsborough Twp.	22,652	28,435	30,901	33,373	35,850	Hillsborough Twp.
Montgomery Twp.	7,970	12,145	13,420	14,725	16,030	Montgomery Twp.
Rocky Hill B.	702	705	710	720	730	Rocky Hill B.
Morrmouth County (Total) (2)	530,913	568,100	591,600	604,300	613,450	Morrmouth County
Millstone Twp.	4,234	5,617	7,000	9,286	11,571	Millstone Twp.

(1) New Jersey Department of Labor. Population Estimates for New Jersey, July 1, 1985.

(2) See methodology in Appendix for details on the source and derivation of County and Municipal Projections.

* Taken from Be87a

Table 5⁺

Population of Counties Within 10 • 50 Miles of PPPL

1985 • 2010

County	1985 Estimates	1995 Projections	2000 Projections	2005 Projections	2010 Projections
New Jersey (1)	7,562,000	8,154,000	8,450,300	8,685,200	8,895,700
Atlantic	205,100	245,100	260,100	272,300	283,200
Bergen	841,200	861,800	878,700	891,900	904,000
Burlington	380,100	437,100	467,200	494,900	521,300
Camden	488,100	555,400	577,200	597,300	616,700
Essex	845,700	794,000	795,500	779,900	762,300
Gloucester	207,100	234,500	249,100	263,500	277,400
Hudson	555,900	560,100	548,100	528,500	507,300
Hunterdon	92,800	104,500	113,000	121,900	131,000
Mercer	317,700	349,700	359,400	364,200	377,100
Middlesex	626,700	695,432	724,610	760,800	791,800
Morrmouth	550,900	568,100	591,600	604,300	613,450
Morris	417,100	479,900	510,500	540,800	570,500
Ocean	380,000	449,600	484,400	515,800	545,900
Passaic	461,600	468,600	469,100	466,500	462,000
Somerset	210,300	250,025	263,800	279,765	295,730
Sussex	119,600	146,100	159,600	172,900	185,700
Union	506,700	534,500	539,700	540,900	540,000
Warren	85,200	92,700	96,200	99,300	101,900
New York (2)	17,783,000	18,314,022	18,548,262	18,750,076	18,948,273
Bronx	1,198,598	1,199,410	1,205,047	1,213,270	1,224,052
Kings	2,248,139	2,228,361	2,232,835	2,242,890	2,254,228
Nassau	1,332,393	1,344,197	1,333,458	1,315,938	1,292,457
New York	1,455,619	1,454,633	1,454,251	1,456,292	1,456,707
Queens	1,917,172	1,919,057	1,925,510	1,933,829	1,953,634
Richmond	371,679	419,706	443,048	445,818	489,111
Pennsylvania (3)	11,863,674	12,100,149	12,101,253	12,161,780	12,222,306
Bucks	512,705	576,716	601,168	636,276	673,345
Chester	334,311	379,733	395,958	418,726	442,802
Delaware	557,180	541,442	531,068	525,279	519,554
Lehigh	277,914	291,083	294,836	300,762	306,808
Monroe	78,967	104,133	117,583	134,162	153,079
Montgomery	663,164	692,521	698,281	712,666	727,346
Northampton	231,430	244,668	249,000	255,275	261,707
Philadelphia	1,637,434	1,599,620	1,513,674	1,472,959	1,433,333

(1) Office of Demographic and Economic Analysis, N.J. Department of Labor and Industry, 1986.

(2) State Data Center, New York State Department of Commerce, 1985.

(3) State Data Center, Pennsylvania Department of Commerce, 1986. See methodology in Appendix for details on 2005 and 2010 projections.

* Taken from Be87a

Table 6 **

Population of Metropolitan Areas Within 50 Miles of PPPL

Metropolitan Areas*	1980 Census	July 1985 Estimate	Percent Change
Allentown-Bethlehem MSA (N J Portion)	84,429	85,200	0.9%
Jersey City, N J PMSA	556,972	555,900	-0.2%
Morrmouth-Ocean PMSA	849,211	910,900	7.3%
Middlesex-Somerset-Hunterdon PMSA	636,383	929,800	4.9%
New York, N Y CMSA	8,274,961	8,410,638	1.6%
Newark, N J PMSA	1,879,147	1,889,000	0.5%
Bergen-Passaic PMSA	1,292,970	1,302,600	0.7%
Philadelphia, P A PMSA (N J Portion)	1,034,109	1,075,300	4.0%
Trenton, N J PMSA	307,863	317,700	3.2%

* MSA = Metropolitan Statistical Area

CMSA = Consolidated Metropolitan Statistical Area

PMSA = Primary Metropolitan Statistical Area

** Taken from Be87a

Source: State of New Jersey, Department of Labor.

New York State Department of Commerce.

Table 7*

1985 Population Estimates Within Annular Sectors, 0 - 10 Miles

Total								
SECTOR	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	0-10 Miles	SECTOR
N	0	100	289	0	68	4,666	5,123	N
NNE	0	20	290	2,697	4,334	9,600	16,741	NNE
NE	0	0	0	0	0	16,799	16,799	NE
ENE	0	1,160	204	200	100	3,792	5,456	ENE
E	0	0	200	100	10	10,238	10,548	E
ESE	0	100	1,600	1,200	219	3,469	6,588	ESE
SE	113	1,200	0	253	161	18,964	20,691	SE
SSE	362	50	150	0	600	8,255	9,417	SSE
S	0	734	3,837	2,312	1,760	4,156	12,799	S
SSW	3	0	2,500	600	100	27,788	30,991	SSW
SW	0	805	10	250	50	18,525	19,640	SW
WSW	0	739	1,000	1,019	1,449	8,095	12,302	WSW
W	0	1,735	5,820	6,777	2,386	6,253	22,971	W
WNW	40	437	772	3,139	0	2,013	6,491	WNW
NW	0	1,020	866	300	350	3,526	6,062	NW
NNW	0	600	499	200	502	7,093	8,894	NNW
Totals	518	8,700	18,037	18,847	12,089	153,232	211,423	Totals

*Taken from Be87a

Table 8*

1995 Population Projections Within Annular Sectors, 0 - 10 Miles

SECTOR	Total							SECTOR
	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	0-10 Miles	
N	0	134	387	0	91	6,241	6,853	N
NNE	0	27	388	3,340	5,242	12,841	21,838	NNE
NE	0	0	0	486	902	21,084	22,472	NE
ENE	0	1,551	273	268	689	5,072	7,853	ENE
E	0	0	268	134	1,678	13,695	15,775	E
ESE	0	827	2,140	1,605	2,235	5,195	12,002	ESE
SE	151	1,605	291	338	493	20,928	23,806	SE
SSE	484	1,454	894	166	803	11,042	14,843	SSE
S	0	982	4,675	3,093	2,354	5,559	16,663	S
SSW	4	188	3,346	2,522	2,908	32,176	41,142	SSW
SW	0	1,077	332	544	2,796	21,450	26,199	SW
WSW	0	989	2,828	1,130	1,594	10,828	17,369	WSW
W	0	2,321	4,005	6,963	2,487	9,277	27,053	W
WNW	53	585	800	3,256	128	4,438	9,260	WNW
NW	0	1,365	898	335	468	4,716	7,782	NW
NNW	0	803	668	268	671	9,487	11,897	NNW
Totals	692	13,908	24,191	24,448	25,539	194,029	282,807	Totals

*Taken from Be87a

Table 9^{*}

2000 Population Projections Within Annular Sectors, 0 - 10 Miles

SECTOR	Total							SECTOR
	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	0-10 Miles	
N	0	146	421	0	99	6,792	7,458	N
NNE	0	29	422	3,635	5,560	13,974	23,620	NNE
NE	0	0	0	656	1,217	22,582	24,455	NE
ENE	0	1,688	297	292	895	5,520	8,692	ENE
E	0	0	292	146	2,261	14,904	17,603	E
ESE	0	1,081	2,329	1,747	2,940	5,799	13,896	ESE
SE	164	1,747	393	368	609	21,615	24,896	SE
SSE	527	1,945	1,154	224	874	12,016	16,740	SSE
S	0	1,069	4,968	3,366	2,562	6,050	18,015	S
SSW	4	254	3,639	3,869	3,890	33,710	45,366	SSW
SW	0	1,172	252	449	4,566	22,473	28,932	SW
WSW	0	1,076	2,334	1,169	1,645	11,784	18,028	WSW
W	0	2,526	6,070	7,028	2,522	10,334	28,480	W
WNW	58	637	810	3,297	173	5,286	10,261	WNW
NW	0	1,485	909	347	509	5,132	8,382	NW
NNW	0	874	727	292	730	10,316	12,939	NNW
Totals	753	15,729	25,037	26,905	31,052	208,287	307,763	Totals

* Taken from Be87a

Table 10*

2005 Population Projections Within Annular Sectors, 0 - 10 Miles

SECTOR	Total							SECTOR
	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	0-10 Miles	
N	0	151	435	0	102	7,014	7,702	N
NNE	0	30	436	3,754	5,688	14,431	24,339	NNE
NE	0	0	0	725	1,344	23,187	25,256	NE
ENE	0	1,743	307	302	978	5,701	9,031	ENE
E	0	0	302	151	2,496	15,392	18,341	E
ESE	0	1,184	2,405	1,804	3,224	6,043	14,660	ESE
SE	169	1,804	434	380	656	21,892	25,335	SE
SSE	544	2,143	1,259	247	903	12,409	17,505	SSE
S	0	1,104	5,086	3,476	2,646	6,243	18,560	S
SSW	4	281	3,758	4,211	4,286	34,329	46,869	SSW
SW	0	1,210	277	492	5,038	22,986	30,003	SW
WSW	0	1,111	2,496	1,185	1,666	12,170	18,628	WSW
W	0	2,609	6,096	7,054	2,536	10,761	29,056	W
WNW	60	658	814	3,313	191	5,628	10,664	WNW
NW	0	1,534	913	352	526	5,300	8,625	NW
NNW	0	903	751	302	754	10,651	13,361	NNW
Totals	777	16,465	25,769	27,748	33,034	214,142	317,935	Totals

* Taken from Be87a

Table 11*

2010 Population Projections Within Annular Sectors, 0-10 Miles

Total								
SECTOR	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	0-10 Miles	SECTOR
N	0	161	465	0	109	7,505	8,240	N
NNE	0	32	466	4,016	5,971	15,441	25,926	NNE
NE	0	0	0	873	1,625	24,521	27,021	NE
ENE	0	1,865	328	322	1,161	6,099	9,775	ENE
E	0	0	322	161	3,016	16,468	19,967	E
ESE	0	1,411	2,574	1,930	3,852	6,580	16,347	ESE
SE	182	1,930	525	407	759	22,503	26,306	SE
SSE	582	2,580	1,491	300	965	13,278	19,196	SSE
S	0	1,181	5,347	3,719	2,831	6,685	19,763	S
SSW	5	339	4,021	4,965	5,161	35,696	50,187	SSW
SW	0.00	1,295	333	542	6,080	23,797	32,047	SW
WSW	0	1,189	2,808	1,219	1,711	13,021	19,948	WSW
W	0	2,791	6,154	7,112	2,568	11,703	30,328	W
WNW	64	703	822	3,349	230	6,383	11,551	WNW
NW	0	1,641	923	363	563	5,671	9,161	NW
NNW	0	965	803	322	807	11,408	14,305	NNW
Totals	833	18,083	27,382	29,602	37,409	226,759	340,068	Totals

* Taken from Be87a

Table 12 *

1985 Population Estimates Within Annular Sectors, 10 - 50 Miles

Total						
SECTOR	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	10-50 Miles	SECTOR
N	66,118	36,704	181,881	68,882	353,586	N
NNE	134,838	226,290	341,211	488,415	1,190,754	NNE
NE	178,403	431,968	1,293,973	3,522,231	5,426,575	NE
ENE	142,397	220,455	1,076,490	1,449,544	2,888,886	ENE
E	52,020	121,842	75,175	0	249,037	E
ESE	38,489	41,729	135,843	0	216,061	ESE
SE	14,219	81,760	179,854	5,852	281,685	SE
SSE	2,926	13,262	20,520	5,784	73,492	SSE
S	5,446	57,129	11,859	2,908	77,342	S
SSW	54,390	61,310	117,286	196,892	429,878	SSW
SW	230,579	361,455	1,147,177	1,032,046	2,771,556	SW
WSW	52,379	151,542	311,433	299,453	814,807	WSW
W	13,955	39,888	106,238	64,611	224,693	W
WNW	8,287	12,555	15,439	252,047	288,328	WNW
NW	13,920	18,653	66,682	86,917	186,172	NW
NNW	26,092	13,716	34,241	22,704	96,753	NNW
Totals	1,034,738	1,890,257	5,115,303	7,529,287	15,569,603	Totals

* Taken from Be87a

Table 13*

1995 Population Estimates Within Annular Sectors, 10 - 50 Miles

Total						
SECTOR	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	10-50 Miles	SECTOR
N	77,600	43,286	209,880	82,344	413,110	N
NNE	151,656	244,555	345,449	501,569	1,243,229	NNE
NE	189,192	466,816	1,282,528	3,531,064	5,469,602	NE
ENE	149,414	244,189	1,075,798	1,444,205	2,913,807	ENE
E	48,224	130,379	80,443	0	259,046	E
ESE	33,170	44,653	147,906	0	225,728	ESE
SE	15,551	95,456	212,796	6,924	330,726	SE
SSE	3,462	15,691	21,278	43,521	86,953	SSE
S	3,792	65,696	13,638	3,437	86,563	S
SSW	58,457	70,504	134,375	224,101	487,438	SSW
SW	254,358	385,409	1,167,023	1,035,758	2,842,548	SW
WSW	55,741	167,298	319,088	309,761	851,889	WSW
W	13,209	44,869	115,585	68,595	242,258	W
WNW	9,332	14,133	17,280	265,316	306,061	WNW
NW	15,675	21,005	72,663	91,959	201,302	NW
NNW	29,653	15,445	38,640	25,334	109,071	NNW
Totals	1,108,692	2,069,384	5,257,370	7,633,889	16,069,335	Totals

* Taken from Be67a

Table 14*

2000 Population Estimates Within Annular Sectors, 10 - 50 Miles

SECTOR	Total					SECTOR
	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	10-50 Miles	
N	81,590	45,762	223,566	89,117	440,035	N
NNE	158,049	250,338	354,421	507,150	1,269,959	NNE
NE	193,977	478,786	1,286,928	3,538,387	5,498,078	NE
ENE	152,903	256,310	1,081,795	1,447,794	2,938,803	ENE
E	47,314	135,772	83,771	0	266,857	E
ESE	31,627	46,500	154,983	0	233,110	ESE
SE	16,320	102,409	229,267	7,460	355,455	SE
SSE	3,730	16,906	26,158	46,890	93,683	SSE
S	3,687	70,220	14,577	3,655	92,139	S
SSW	60,661	75,359	142,235	234,143	512,399	SSW
SW	262,872	389,374	1,137,316	1,011,964	2,801,526	SW
WSW	57,234	172,994	316,136	311,387	857,751	WSW
W	13,585	46,771	118,755	69,700	248,812	W
WNW	10,091	15,112	18,138	269,393	312,733	WNW
NW	16,950	22,713	75,734	93,637	209,035	NW
NNW	31,170	16,701	40,885	26,602	115,358	NNW
Totals	1,141,761	2,142,027	5,304,664	7,657,280	16,245,732	Totals

* Taken from Be87a

Table 15*

2010 Population Estimates Within Annular Sectors, 10 - 50 Miles

SECTOR	Total					SECTOR
	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	10-50 Miles	
N	91,018	51,262	250,373	102,263	494,916	N
NNE	172,722	258,877	362,497	510,423	1,304,520	NNE
NE	209,861	499,736	1,240,255	3,552,301	5,522,153	NE
ENE	164,784	277,228	1,099,303	1,464,153	3,005,468	ENE
E	47,676	140,787	86,865	0	275,327	E
ESE	30,472	48,217	163,289	0	241,978	ESE
SE	17,263	114,276	258,374	8,407	398,321	SE
SSE	4,203	19,052	29,479	52,843	105,577	SSE
S	4,009	78,351	16,265	4,007	102,632	S
SSW	65,172	84,086	156,390	252,607	558,255	SSW
SW	284,516	410,918	1,123,253	998,753	2,817,440	SW
WSW	61,714	190,521	321,293	322,263	895,791	WSW
W	15,337	52,386	128,998	73,884	270,605	W
WNW	11,698	17,340	20,389	281,867	331,295	WNW
NW	19,650	26,331	81,471	98,437	225,889	NW
NNW	34,761	19,362	45,199	28,849	128,171	NNW
Totals	1,234,856	2,288,731	5,403,694	7,751,059	16,678,339	Totals

* Taken from Be87a

TABLE 16 (Ku86b)

SECTORIZED POPULATION DATA TO 1 MILE

		radial distances (m)*				
		<u>50</u>	<u>125</u>	<u>375</u>	<u>1105</u>	<u>2416</u>
S	n	0	0	0	377	486
	nnw	0	0	63	0	469
	nw	0	0	0	20	416
E	wnw	0	0	0	800	830
	w	0	0	103	0	1587
C	ws w	0	0	116	192	749
	sw	0	0	116	317	12
T	ssw	0	0	0	950	247
	s	0	0	317	317	820
O	sse	0	0	0	0	3848
	se	0	0	18	0	64
R	ese	0	0	73	0	60
	e	0	0	73	0	30
	ene	0	0	18	34	17
	ne	0	0	0	250	66
	nne	0	0	0	186	25

* The radii shown are midpoints of the sector radial boundaries.

Table 17. USGS Well Water Results (TW1 TW10) CY89

	Location of Well-->	D-Site TW1	D-Site TW1	D-Site TW1	D-Site TW10	D-Site TW10
	Collection Date-->	1/6/89	3/28/89	9/27/89	3/28/89	9/27/89
Units	Parameter					
ug/l	1,1,1-Trichloroethane Total	0.2	0.3	0.4	<0.2	<0.2
ug/l	1,1,2,2-Tetrachloroethane Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	1,1,2-Trichloroethane Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	1,1-Dichloroethylene Total	<0.2	<0.2	0.2	<0.2	<0.2
ug/l	1,1-Dichloroethylene Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	1,12-Benzoperylene Total		<10.0		<10.0	
ug/l	1,2,4-Trichlorobenzene Total		<5.0		<5.0	
ug/l	1,2,5,6-Dibenzanthracene Total		<10.0		<10.0	
ug/l	1,2-Benzanthracene Total		<5.0		<5.0	
ug/l	1,2-Dibromoethane Water Whole T	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	1,2-Dichlorobenzene Total	<0.2	<5.0	<0.2	<5.0	<0.2
ug/l	1,2-Dichloroethane Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	1,2-Dichloropropane Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	1,2-Transdichloroethene Total	<0.2	0.2	0.2	<0.2	<0.2
ug/l	1,3-Dichlorobenzene Total	<0.2	<5.0	<0.2	<5.0	<0.2
ug/l	1,3-Dichloropropene Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	1,4-Dichlorobenzene Total	<0.2	<5.0	<0.2	<5.0	<0.2
ug/l	2,4,6-Trichlorophenol Total		<20.0		<20.0	
ug/l	2,4-Dichlorophenol Total		<5.0		<5.0	
ug/l	2,4-Dimethylphenol Total		<5.0		<5.0	
ug/l	2,4-Dinitrophenol Total		<20.0		<20.0	
ug/l	2,4-Dinitrotoluene Total		<5.0		<5.0	
ug/l	2,6-Dinitrotoluene Total		<5.0		<5.0	
ug/l	2-Chloroethylvinyl Ether Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	2-Chloronaphthalene Total		<5.0		<5.0	
ug/l	2-Chlorophenol Total		<5.0		<5.0	
ug/l	2-Nitrophenol Total		<5.0		<5.0	
ug/l	4,6-Dinitro-Orthocresol Total		<30.0		<30.0	
ug/l	4-Bromophenyl Phenyl Ether Total		<5.0		<5.0	
ug/l	4-Chlorophenyl Phenyl Ether Total		<5.0		<5.0	
ug/l	4-Nitrophenol Total		<30.0		<30.0	
ug/l	Acenaphthylene Total		<5.0		<5.0	
Deg C	Air Temperature	23	19	23	20	
mg/l	Alkalinity Lab		151	154	151	138
ug/l	Aluminum, Dissolved			10		<10
ug/l	Arsenic, Dissolved			<1.0		<1.0
ug/l	Anthracene Total		<5.0		<5.0	
ug/l	Aroclor 1016 PCB Total		<0.1		<0.1	
ug/l	Aroclor 1221 PCB Total		<0.1		<0.1	
ug/l	Aroclor 1232 PCB Total		<0.1		<0.1	
ug/l	Aroclor 1242 PCB Total		<0.1		<0.1	
ug/l	Aroclor 1248 PCB Total		<0.1		<0.1	
ug/l	Aroclor 1254 PCB Total		<0.1		<0.1	
ug/l	Aroclor 1260 PCB Total		<0.1		<0.1	
ug/l	Barium, Dissolved		330	320	430	430
ug/l	Benzene Total	0.2	0.2	<0.2	0.2	<0.2
ug/l	Benzo(a)pyrene Total		<10.0		<10.0	
ug/l	Benzo(b)fluoranthene Total		<10.0		<10.0	
ug/l	Beryllium, Dissolved		<0.5	<0.5	<0.5	<0.5
ug/l	Bis (2-Ethyl Hexyl)Phthalate Total		<5.0		<5.0	
ug/l	Bis 2-Chloroethoxy Methane Total		<5.0		<5.0	
ug/l	Bis 2-Chloroethyl Ether Total		<5.0		<5.0	
ug/l	Bis 2-Chloroisopropyl Ether Total		<5.0		<5.0	
ug/l	Boron, Dissolved		20	20	10	20
ug/l	Bromoform Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Cadmium, Dissolved		<1.0	<1.0	<1.0	<1.0
mg/l	Calcium, Dissolved		49	47	50	49

Table 17. USGS Well Water Results (TW1 TW10) CY89

Location of Well-->		D-Site TW1	D-Site TW1	D-Site TW1	D-Site TW10	D-Site TW10
Collection Date-->		1/6/89	3/28/89	9/27/89	3/28/89	9/27/89
Units	Parameter					
ug/l	Carbon Tetrachloride Total	<0.2	<0.2	<0.2	<0.2	<0.2
mg/l	Carbon, Organic, Dissolved		0.6	0.7	0.5	0.6
mg/l	Chloride, Dissolved		14	13	14	12
ug/l	Chlorobenzene Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Chlorodibromomethane Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Chloroethane Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Chloroform Total	<0.2	<0.2	0.2	<0.2	<0.2
ug/l	Chromium, Dissolved		<5.0	<5.0	<5.0	<5.0
ug/l	Chromium, Hexavalent, Dissolved		1	2	1	1
ug/l	Chrysene Total		<10.0		<10.0	
ug/l	Cis-1,3-Dichloropropene Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Cobalt, Dissolved		<3.0	<3.0	<3.0	<3.0
ug/l	Copper, Dissolved		<10	<10	<10	<10
ug/l	Di-N-Butyl Phthalate Total		<5.0		<5.0	
ug/l	Di-N-Octyl Phthalate Total		<10.0		<10.0	
ug/l	Dichlorobromomethane Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Dichlorodifluoromethane Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Diethyl Phthalate Total		<5.0		<5.0	
ug/l	Dimethyl Phthalate Total		<5.0		<5.0	
ug/l	Ethylbenzene Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Fluoranthene Total		<5.0		<5.0	
ug/l	Fluorene Total		<5.0		<5.0	
mg/l	Fluoride, Dissolved		0.1	0.1	0.1	0.1
ug/l	Hexachlorobenzene Total		<5.0		<5.0	
ug/l	Hexachlorobutadiene Total		<5.0		<5.0	
ug/l	Hexachlorocyclopentadiene Total		<5.0		<5.0	
ug/l	Hexachloroethane Total		<5.0		<5.0	
ug/l	Indeno (1,2,3-CD) Pyrene Total		<10.0		<10.0	
mg/l	Iodide, Dissolved		0.003	0.003	0.003	0.003
ug/l	Iron, Dissolved		44	300	490	930
ug/l	Isophorone Total		<5.0		<5.0	
ug/l	Lead, Dissolved		<10	10	<10	<10
ug/l	Lithium, Dissolved		8	7	8	8
mg/l	Magnesium, Dissolved		15	14	13	13
ug/l	Manganese, Dissolved		150	66	340	350
ug/l	Methylbromide Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Methylene Chloride Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Molybdenum, Dissolved		<10	<10	<10	10
ug/l	N-Butyl Benzyl Phthalate Total		<5.0		<5.0	
ug/l	N-Nitrosodi-N-Propylamine		<5.0		<5.0	
ug/l	N-Nitrosodimethylamine Total		<5.0		<5.0	
ug/l	N-Nitrosodiphenylamine Total		<5.0		<5.0	
ug/l	Naphthalene Total		<5.0		<5.0	
ug/l	Nickel, Dissolved		<10	<10	<10	<10
ug/l	Nitrobenzene Total		<5.0		<5.0	
mg/l	Nitrogen Ammonia, Dissolved		<0.01	0.02	0.05	0.03
mg/l	Nitrogen, Ammonia + Organic Dis.		<0.2	0.8	<0.20	<0.20
mg/l	Nitrogen, Nitrite, Dissolved		<0.01	<0.01	<0.01	<0.01
mg/l	Nitrogen, NO2+NO3, Dissolved		<0.1	0.19	<0.1	<0.1
mg/l	Oxygen, Dissolved		0.3	0.2	0.5	0.1
ug/l	Parachlorometacresol Total		<30.0		<30.0	
ug/l	Pentachlorophenol Total		<31.0		<31.0	
	pH Field		7.22	7.23	7.56	7.42
	pH Lab		7.3		7.4	
ug/l	Phenanthrene Total		<5.0		<5.0	
ug/l	Phenol (C6H5 OH) Total		<5.0		<5.0	
mg/l	Phosphorous Ortho, Dissolved		0.02	0.01	<0.01	<0.01

Table 17. USGS Well Water Results (TW1 TW10) CY89

Location of Well-->		D-Site TW1	D-Site TW1	D-Site TW1	D-Site TW10	D-Site TW10
Collection Date-->		1/6/89	3/28/89	9/27/89	3/28/89	9/27/89
Units	Parameter					
mg/l	Potassium, Dissolved		1.7	2.5	1.7	1.7
ug/l	Pyrene Total		<5.0		<5.0	
mg/l	Silica, Dissolved		27	27	26	26
ug/l	Silver, Dissolved		<1.0	2	<1.0	2
mg/l	Sodium, Dissolved		11	11	10	9.9
mg/l	Solids, Residue at 180 Deg. C, Dis.		238	230	225	215
mg/l	Solids, Sum of Constituents, Dis.		232	230	225	215
us/cm	Specific Conductance		381	347	360	359
us/cm	Specific Conductance Lab		386	383	371	374
ug/l	Strontium, Dissolved		390	380	440	440
ug/l	Styrene Total	<0.2	<0.2	<0.2	<0.2	<0.2
mg/l	Sulfate, Dissolved		23	22	18	18
ug/l	Tetrachloroethylene Total	2.2	4.3	5.1	1	1.1
ug/l	Toluene Total	0.9	0.3	<0.2	0.2	<0.2
ug/l	Trans-1,3-Dichloropropene Total	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Trichloroethylene Total	0.2	0.2	0.2	0.2	0.2
ug/l	Trichlorofluoromethane Total	<0.2	<0.2	<0.2	<0.2	<0.2
pCi/l	Tritium Total		57		58	
ug/l	Vanadium, Dissolved		<1.0	<1.0	<1.0	<2.0
ug/l	Vinyl Chloride Total	<0.2	<0.2	<0.2	<0.2	<0.2
Deg. C	Water Temperature		12.5	16	12.5	17.5
ug/l	Xylene Total Water Whole Tot Rec	<0.2	<0.2	<0.2	<0.2	<0.2
ug/l	Zinc, Dissolved		8	19	5	14

Table 18. Water Quality Monitoring Data

Forestal Campus, Princeton University													
Station: B1 (Bee Brook)													
	Collection Date -->	1/23/89	2/28/89	3/20/89	4/18/89	5/22/89	6/19/89	7/19/89	8/5/89	9/28/89	10/23/89	11/20/89	12/20/89
Units	Parameter	3:45 PM	12:30 PM	12:45 PM	1:40 PM	1:00 PM	2:40 PM	1:35 PM	2:15 PM	11:45 AM	3:50 PM	10:55 AM	1:30 PM
mg/l CaCO3 eq	Alkalinity	16	9.9	10.3	34	24	20	23	22	15	35	19	18
mg/l O2	BOD5	<2.0	<2	<1	<1	<2	<1	1.9	2.5	5	<1.0	<1.0	<1
mg/l CaCO3 eq	Calcium Hardness	16	15	18	32	22	22	27	20	17	38	17	14
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O2	COD	<2.0	/	<2.0	35	38	8	18	<5.0	14	5	<5.0	<5.0
mg/l Cu	Copper	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	0.07	<0.02	<0.02	0.06	<0.02
mg/l O2	Dissolved Oxygen	10.2	11	10	10	9.4	8.8	8.6	8.8	9.2	9	10.1	12
mg/l Cu eq.	EDTA	0.06	0.12	0.04	0.8	0.12	0.58	0.18	0.16	1.2	2.7	2.01	0.88
MPN/100 ml	Total Coliform Count	170	300	900	50	>1600	900	900	900	>1600	500	>1600	>1600
l3/sec	Flow	0.07	0.17	0.1	0.21	0.22	0.12	0.17	0.03	0.13	0.19	0.15	0.06
mg/l Fe	Iron	0.99	0.23	0.33	0.36	0.42	0.7	0.41	0.37	0.29	0.34	0.76	0.17
mg/l N	Nitrogen, Total Kjeldahl	0.4	0.41	0.63	0.53	0.11	0.76	0.7	0.7	0.68	0.76	1.0	0.45
mg/l N	Nitrogen, Nitrate	0.74	0.76	0.69	0.71	0.98	1.4	1.2	1.6	1.1	0.79	1.2	1.2
mg/l	Oil & Grease	<0.5	2.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	0.8	<0.5
unit	pH	7.2	6.6	6.9	7.3	7	7.4	7.1	7.5	7	7.1	7	7.3
mg/l P	Phosphate, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.10	<0.1	<0.1	<0.1	<0.1	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.10	<0.1	<0.1	<0.1	<0.1	<0.1
mg/l	Solids - Dissolved	112	157	149	126	144	130	114	133	106	124	95	147
mg/l	Solids - Suspended	6	8	13	15	4	7	14	13	10	3	16	8
mg/l SO4	Sulfate	17	13	23	23	-	34	24	23	18	17	18.5	19
Deg C	Temperature	3	5	6.5	16.5	17	21	19	16	13	12	7	2
NTU	Turbid ty	3.4	3.6	3.6	4.4	4.8	5	7.2	8	8.8	3.8	5.9	4.1
mg/l Zn	Zinc	0.03	0.03	0.04	0.02	0.02	0.01	<0.01	<0.02	<0.02	0.03	<0.02	<0.02
	Clarity	Clear	Clear	Clear	Clear	Sl. Cloudy	Clear	Sl. Cloudy	Clear	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Clear

Table 19. Water Quality Monitoring Data

		Forrestal Campus, Princeton University Station: B2 (Boe Brook)											
Collection Date -->		1/23/89	2/28/89	3/20/89	4/18/89	5/22/89	6/19/89	7/19/89	9/5/89	9/26/89	10/23/89	11/20/89	12/20/89
Units	Parameter	4:30 PM	11:50 PM	12:15 PM	12:40 PM	12:30 PM	2:40 PM	1:35 PM	1:45 PM	11:15 AM	3:30 PM	9:40 AM	11:30 AM
mg/l CaCO ₃ eq	Alkalinity	33	16	18	26	22	30	28	39	53	55	40	40
mg/l O ₂	BOD ₅	42	<2	<1	<1	<2	<1	2.5	<1	1.5	<1.0	<1.0	2
mg/l CaCO ₃ eq	Calcium Hardness	32	24	26	22	21	31	30	34	48	46	31	38
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	COD	<2.0	11	12	18	40	14	19	9	14	10	20	<5.0
mg/l Cu	Copper	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.06	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	Dissolved Oxygen	10	12	10.8	10.6	9.6	9.2	9	9.4	8.9	9.2	10.2	10.8
mg/l Cu eq.	EDTA	0.1	<0.02	0.05	0.18	0.24	0.78	0.18	0.28	0.82	1.3	0.152	1
MPN/100 ml	Total Coliform Count	900	30	900	80	1600	≥1600	≥1600	≥1600	≥1600	≥1600	360	280
lit/sec	Flow	0.13	0.32	0.26	0.32	0.28	0.23	0.21	0.1	0.34	0.5	0.25	0.16
mg/l Fe	Iron	0.3	0.32	0.32	0.3	0.47	0.55	0.4	0.22	0.32	0.45	0.33	0.16
mg/l N	Nitrogen, Total Kjeldahl	0.5	<0.1	0.58	0.57	0.75	0.52	0.12	0.36	0.64	0.56	<1.0	0.65
mg/l N	Nitrogen, Nitrate	0.86	0.74	0.71	0.6	0.85	1.7	1.5	0.95	1.3	1	1.1	1.4
mg/l	Oil & Grease	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50	2.6	<0.5	0.6	<0.5	0.5	<0.5
unit	pH	7.2	6.9	7.1	7.5	7.1	7.6	7.3	7.8	7.5	7.3	7.2	7.5
mg/l P	Phosphate, Total	0.25	<0.1	<0.1	<0.1	0.1	0.15	0.1	0.3	0.5	0.4	0.15	0.1
mg/l P	Phosphate, Ortho	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	0.2	0.2	0.1	<0.1	<0.1
mg/l	Solids - Dissolved	129	174	183	121	144	137	128	152	127	152	83	166
mg/l	Solids - Suspended	4	7	13	8	12	1	29	2	4	9	12	6
mg/l SO ₄	Sulfate	16	21	21	25	--	26	23	23	21	22	20	19
°C	Temperature	6	7	8	18	17	21	19	17	16	15	10	4
NTU	Turbidity	3.9	3.7	3.8	2.9	4.9	4	5	4.6	6	7.7	5.7	3.5
mg/l Zn	Zinc	0.02	0.04	0.06	0.02	0.02	0.01	0.0	<0.02	<0.02	0.03	0.4	0.02
	Clarity	Sl. Cloudy	Clear	Clear	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Clear	Clear	Clear	Sl. Cloudy	Clear	Clear

Table 21. Water Quality Monitoring Data

					Forrestal Campus, Princeton University								
					Station: D1 (Drainage Ditch)								
	Collection Date -->	1/23/89	2/28/89	3/20/89	4/18/89	5/22/89	6/19/89	7/19/89	9/5/89	9/28/89	10/23/89	11/20/89	12/20/89
Units	Parameter	2:10 PM	11:10 AM	2:00 PM	11:50 AM	11:45 AM	12:25 PM	2:20 PM	1:00 PM	10:30 AM	2:40 PM	10:25 AM	11:30 AM
mg/l CaCO3 eq	Alkalinity	43	22	30	28	57	33	29	51	30	27	41	46
mg/l O2	BOD5	<2.0	2.2	1.6	<1	<2	1.6	2.3	2	3	<1.0	<1.0	2
mg/l CaCO3 eq	Calcium Hardness	47	55	42	32	30	21	38	50	33	29	38	42
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O2	COD	10	10	<2	22	50	16	13	<5.0	13	8	<5.0	<5
mg/l Cu	Copper	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O2	Dissolved Oxygen	9.8	11	10.2	9.2	9.5	9.1	8.4	8.3	8	8.2	9.3	10.4
mg/l Cu eq.	EDTA	0.14	0.16	0.1	0.08	0.1	0.16	0.24	0.09	0.66	2.4	0.14	0.3
MPN/100 ml	Total Coliform Count	<2	<2	4	<2	1600	23	1600	22	>1600	>1600	8	9
lit3/sec	Flow	0.08	0.08	0.08	0.07	0.08	0.7	0.06	0.07	0.08	NT*	0.07	0.08
mg/l Fe	Iron	0.29	0.69	0.64	0.68	0.34	1.3	0.45	0.22	0.4	0.88	0.24	0.2
mg/l N	Nitrogen, Total Kjeldahl	0.4	0.3	0.62	0.73	0.08	0.56	0.12	0.69	1.68	0.92	1.4	0.73
mg/l N	Nitrogen, Nitrate	1.4	1.6	2	1.3	2.4	1.8	1.3	0.91	1.5	0.97	1.1	1.6
mg/l	Oil & Grease	<0.5	2	<0.5	<0.5	<0.5	<0.50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
unit	pH	7.2	6.7	7.1	7	6.7	7.7	7.2	7.7	7	6.8	7.2	7.8
mg/l P	Phosphate, Total	1.3	0.55	1.4	1.5	1.2	1.7	0.75	1.4	1.5	1.2	0.7	0.7
mg/l P	Phosphate, Ortho	0.5	0.15	0.25	0.35	0.3	0.55	0.3	0.6	0.4	0.2	0.25	0.2
mg/l	Solids - Dissolved	156	212	200	143	162	151	149	190	132	131	75	171
mg/l	Solids - Suspended	13	13	17	11	11	10	9	11	4	17	3	1
mg/l SO4	Sulfate	34	28	36	48	--	40	21	24	21	17	24	24
Deg C	Temperature	8	11	12	14	18	21	21	22	21	18	15	11
NTU	Turbidity	5.2	11.5	6.7	11	6	11	6.3	7.3	6.3	13	3.1	2.6
mg/l Zn	Zinc	0.02	0.06	0.03	0.03	0.04	<0.01	0.03	<0.02	<0.02	0.06	0.03	<0.02
	Clarity	Clear	Sl. Cloudy	Clear	Clear	Sl. Cloudy	Sl. Cloudy	Clear	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Clear	Clear
*None Taken													

Table 22. Water Quality Monitoring Data

		Forrestal Campus, Princeton University Station: D2 (Drainage Ditch)											
Collection Date -->		1/23/88	2/26/89	3/20/89	4/18/89	5/22/89	6/19/89	7/19/89	9/5/89	9/28/89	10/23/89	11/20/89	12/20/89
Units	Parameter	4:00 PM	12:50 PM	2:55 PM	2:50 PM	2:25 PM	-	-	-	-	-	-	-
mg/l CaCO ₃ eq	Alkalinity	64	50	51	50	55	60	63	82	68	60	57	72
mg/l O ₂	BOD ₅	<2.0	<1	<1	<1	<2	1	1.9	2	5	1	<1.0	<1
mg/l CaCO ₃ eq	Calcium Hardness	60	61	38	55	53	56	58	68	58	51	43	62
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	COD	<2.0	8.6	2	16	48	<2	5	<5.0	6	<6.0	<5.0	<5.0
mg/l Cu	Copper	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.07	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	Dissolved Oxygen	9.2	10	9.8	9.8	10	11	10.4	12	7.7	8.9	8.4	9.6
mg/l Cu eq.	EDTA	<0.02	0.14	0.16	0.1	0.12	<0.02	0.48	0.24	0.84	1.7	0.14	0.74
MPN/100 ml	Total Coliform Count	38	≥1600	170	170	>1600	1600	300	1600	≥1600	≥1600	170	70
ft ³ /sec	Flow	0.06	0.09	0.08	0.04	0.12	0.4	0.04	0.05	0.21	0.04	0.05	0.07
mg/l Fe	Iron	0.49	1.1	0.76	0.37	0.49	0.54	0.59	0.09	0.24	0.47	0.13	0.16
mg/l N	Nitrogen, Total Kjeldahl	0.4	0.24	0.6	0.22	0.32	0.83	<0.10	0.37	0.78	0.35	<1.0	0.59
mg/l N	Nitrogen, Nitrate	1.4	1.3	1	3.9	1.7	1.6	1.03	0.96	1.4	0.91	1.2	1.4
mg/l	Oil & Grease	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	<0.5	<0.5	<0.5	<0.5
unit	pH	7.2	6.8	7.3	6.9	7	7.3	7.5	8.3	7.3	7.2	6.8	7.3
mg/l P	Phosphate, Total	0.65	0.35	0.55	0.5	0.5	0.7	0.35	0.55	0.5	0.6	0.25	0.3
mg/l P	Phosphate, Ortho	0.3	0.15	0.2	0.25	0.2	0.3	0.2	0.4	0.2	0.2	0.15	0.1
mg/l	Solids - Dissolved	170	540	211	247	209	182	174	210	185	171	84	211
mg/l	Solids - Suspended	4	18	40	6	7	3	14	1	6	11	2	1
mg/l SO ₄	Sulfate	22	28	39	30	-	30	28	15	22	23	22	24
Deg C	Temperature	10	11	11	18.5	21	23	21	21	20	17	14	8
NTU	Turbidity	3.9	19	12	7.2	6.4	6.3	9.2	1.4	4.1	8.2	2.2	1.7
mg/l Zn	Zinc	0.02	0.04	0.04	0.03	0.03	0.04	0.02	<0.02	<0.02	0.03	0.02	<0.02
	Clarity	Clear	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Clear	Clear	Clear	Clear	Clear	Clear

Table 23. Water Quality Monitoring Data

Forrestal Campus, Princeton University Station: E1 (Elizabethtown Water)													
Collection Date -->		1/23/89	2/26/89	3/26/89	4/18/89	5/22/89	6/19/89	7/19/89	9/5/89	9/28/89	10/23/89	11/20/89	12/20/89
Units	Parameter	1:55 PM	10:50 AM	1:40 PM	11:40 AM	11:25 AM	12:10 PM	2:10 PM	1:25 PM	10:45 AM	3:00 PM	10:40 AM	1:50 AM
mg/l CaCO3 eq	Alkalinity	6.1	41	44	31	32	65	69.5	68	109	46	53	51
mg/l CaCO3 eq	Calcium Hardness	71	82	66	47	50	68	74.2	72	75	36	65	56
mg/l Cu	Copper	<0.02	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	0.06	<0.02	<0.02	<0.02	<0.02
MPN/100 ml	Total Coliform Count	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
mg/l Fe	Iron	0.19	0.06	0.23	0.06	0.04	<0.02	0.04	0.06	<0.02	0.19	<0.02	0.04
mg/l N	Nitrogen, Total Kjeldahl	0.1	0.34	0.87	0.32	0.32	0.43	0.45	0.39	0.7	0.45	1.1	0.87
mg/l N	Nitrogen, Nitrate	2.3	2.1	1.7	3.9	2.6	2.7	2.1	2	2.6	1.2	4.6	1.5
unit	pH	7	6.9	7.3	6.8	6.9	7.3	7.1	7.2	7.5	7	7.2	7.1
mg/l P	Phosphate, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.10	0.1	0.1	0.2	<0.1	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.10	0.1	<0.1	0.1	<0.1	<0.1
mg/l	Solids - Dissolved	205	184	236	139	185	187	191	220	237	148	143	188
mg/l Mn	Manganese	<0.01	0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
mg/l Cl	Chloride	26	22	49	19	-	20	25	22.5	22	15	25	24
mg/l SO4	Sulfate	29	36	30	35	-	61	43	39	38	38	33	34
Deg C	Temperature	8	7	6	11.5	16	14	19	20	18	15	13	6
NTU	Turbidity	0.64	0.59	0.46	0.48	0.35	0.37	0.51	0.35	0.36	0.33	0.3	0.26

Table 24. Water Quality Monitoring Data

Forrestal Campus, Princeton University													
Station: MI (Millsboro River)													
Units	Collection Date -->	1/23/89	2/28/89	3/20/89	4/18/89	5/22/89	6/19/89	7/19/89	9/5/89	9/28/89	10/23/89	11/20/89	12/20/89
	Parameter	3:10 PM	3:50 PM	5:05 PM	10:45 AM	10:30 AM	11:35 AM	7:05 PM	11:20 AM	10:55 AM	4:10 PM	4:50 PM	3:05 PM
mg/l CaCO3 eq	Alkalinity	9.7	14	13	11	15	18	14	25	14	13	19	24
mg/l CaCO3 eq	Calcium Hardness	28	22	28	21	20	21	19	26	20	15	21	28
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu	Copper	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu eq.	EDTA	0.08	0.04	0.08	0.14	0.08	-	0.46	<0.02	0.44	1.2	0.18	1.16
mg/l Fe	Iron	0.46	1.6	0.74	0.93	1.4	3.1	2	0.64	1.2	1.2	0.76	0.37
mg/l N	Nitrogen, Nitrate	3.8	2	2.4	1.6	2	2.2	1.14	3.9	1.3	1.01	0.72	2.2
mg/l	Oil & Grease	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50	3	<0.5	1	<0.5	<0.5	<0.5
unit	pH	6.9	6.7	6.7	6.6	6.5	7	6.9	7.2	6.7	6.6	6.9	6.8
mg/l P	Phosphate, Total	0.15	0.2	0.1	0.15	0.2	0.2	0.26	0.2	0.2	0.1	0.1	0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.10	<0.1	<0.1	<0.10	<0.1	<0.1
mg/l	Solids - Dissolved	148	154	199	99	133	113	93	163	75	92	71	140
mg/l	Solids - Suspended	18	27	14	17	12	12	17	9	13	66	8	4
mg/l SO4	Sulfate	20	29	26	28	-	15	14	15	17	5.5	10	22
NTU	Turbidity	3.8	23	7.8	11	11.8	13	14	6.9	9.4	11	5.1	3.8
mg/l Zn	Zinc	0.03	0.04	0.03	0.06	0.02	0.01	0.01	<0.02	<0.01	<0.02	<0.02	<0.02
	Clarity	Clear	Clear	Clear	Sl Cloudy	Sl Cloudy	Clear	Sl Cloudy	Clear	Mod Cloudy	Sl Cloudy	Sl Cloudy	Sl Cloudy

Table 25. Water Quality Monitoring Data

Forrestal Campus, Princeton University													
Station: Pt (Off-Site Location)													
Units	Collection Date -->	1/23/89	2/26/89	3/20/89	4/18/89	5/22/89	6/19/89	7/19/89	9/5/89	9/28/89	10/23/89	11/20/89	12/20/89
	Parameter	2:20 PM	1:50 PM	4:15 PM	10:04 AM	9:35 AM	10:50 AM	5:50 PM	9:20 AM	10:10 AM	3:20 PM	4:15 PM	2:20 PM
mg/l CaCO ₃ eq	Alkalinity	9.9	7.9	9.3	9.5	1.9	1.8	1.1	2.9	1.0	9.6	11.6	1.2
mg/l CaCO ₃ eq	Calcium Hardness	2.9	1.8	2.6	1.9	1.5	2.1	1.7	2.6	1.7	9.4	2.1	3.0
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu	Copper	<0.02	0.06	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu eq	EDTA	<0.02	0.13	0.12	0.12	0.06	-	0.34	<0.02	0.2	2	0.14	0.14
mg/l Fe	Iron	1.3	2.2	1.8	2.4	2.9	4	2.15	1.02	1.2	1.2	0.53	0.72
mg/l N	Nitrogen, Nitrate	2.9	1.8	1.6	2.9	2	1.5	1.4	0.95	1.2	0.95	3.2	2.2
mg/l	Oil & Grease	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50	0.8	<0.5	<0.5	<0.5	<0.5	<0.5
unit	pH	8.4	6.3	6.6	6.4	6.4	7.1	6.7	7	6.5	6.4	6.7	6.4
mg/l P	Phosphate, Total	0.1	0.2	0.2	0.2	0.4	0.3	0.25	0.1	0.2	0.1	<0.1	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.10	<0.1	<0.1	<0.1	<0.1	<0.1
mg/l	Solids - Dissolved	133	104	158	92	143	99	96	137	103	132	120	163
mg/l	Solids - Suspended	34	17	32	37	44	32	29	9	19	11	9	9
mg/l SO ₄	Sulfate	25	36	32	30	-	18	14	19	18	11	21	25
NTU	Turbidity	10	30	18	28	28	28	20	6.5	11.5	11	4.9	6.8
mg/l Zn	Zinc	0.01	0.04	0.04	0.03	0.02	<0.01	0.01	<0.02	<0.02	0.04	<0.02	<0.02
	Clarity	Sl. Cloudy	Clear	Mod Cldy	Mod Cldy	Mod Cldy	Mod Cldy	Mod Cldy	Sl. Cloudy	Sl. Cloudy	Clear	Clear	Sl. Cloudy

Table 26. Water Quality Monitoring Data

Forrestal Campus, Princeton University													
Station: P2 (Off-Site Location)													
	Collection Date -->	1/23/89	2/28/89	3/20/89	4/18/89	5/22/89	6/19/89	7/19/89	9/5/89	9/28/89	10/23/89	11/20/89	12/20/89
Units	Parameter	2:35 PM	2:05 PM	4:30 PM	10:20 AM	9:55 AM	11:05 AM	6:30 PM	9:40 AM	10:25 AM	3:30 PM	4:30 PM	2:35 PM
mg/l CaCO3 eq	Alkalinity	12	8.9	9.5	9.8	11	15	12	23	9	6.6	13.6	17
mg/l CaCO3 eq	Calcium Hardness	17	11	14	10.3	10.6	13	13	20	11	8.2	13.6	18
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu	Copper	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.02	<0.02	<0.02
mg/l Cu eq	EDTA	0.04	0.14	<0.02	0.12	0.3	-	0.32	0.08	0.16	1.4	0.13	0.38
mg/l Fe	Iron	0.54	0.32	0.31	4.6	1.2	2.9	1.51	0.59	1	1.1	0.68	0.58
mg/l N	Nitrogen, Nitrate	2.7	1.8	1.7	1.9	3.7	1.03	1.2	4.5	1.3	0.89	2.7	2.1
mg/l	Oil & Grease	<0.5	<0.5	1	<0.5	<0.5	<0.5	1	<0.5	<0.5	<0.5	1.2	<0.5
unit	pH	6.6	6.5	6.7	6.4	6.4	6.8	6.7	7	6.4	6.3	6.8	6.6
mg/l P	Phosphate, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.1	<0.1	<0.1	<0.1	<0.1
mg/l P	Phosphate, Ortho	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.1	<0.1	<0.1	<0.1	<0.1
mg/l	Solids - Dissolved	86	78	108	62	128	89	84	129	87	95	95	107
mg/l	Solids - Suspended	16	12	10	12	5	3	7	<1.0	3	5	9	14
mg/l SO4	Sulfate	12	15	21	22	-	4	4	5	7	14	12	10
NTU	Turbidity	4.2	7.8	3.7	5	4.2	5.7	6.7	3	4.8	5.2	2.9	4.6
mg/l Zn	Zinc	0.03	0.04	0.03	0.03	0.02	<0.01	0.01	<0.02	<0.02	0.03	<0.02	<0.02
	Clarity	Clear	Clear	Clear	Sl.Cloudy	Clear	Sl.Cloudy	Clear	Sl.Cloudy	Sl.Cloudy	Mod.Cloudy	Clear	Sl.Cloudy

Table 27. Water Quality Monitoring Data

Forrestal Campus, Princeton University					
Station: W4 (C-Site Underground Well)					
	Collection Date -->	3/20/89	6/19/89	9/28/89	12/20/89
Units	Parameter	3:00 PM	1:35 PM	12:25 PM	12:30 PM
mg/l CaCO ₃ eq.	Alkalinity	111	120	108	120
mg/l CaCO ₃ eq.	Calcium Hardness	60	63	65	62
mg/l Cu	Copper	0.03	<0.02	<0.02	<0.02
MPN/100 ml	Total Coliform Count	<2	<2	2	2
mg/l Fe	Iron	0.93	1.5	1.2	0.68
mg/l N	Nitrogen, Total Kjeldahl	0.35	0.24	0.56	0.67
mg/l N	Nitrogen, Nitrate	0.15	0.14	0.15	0.05
unit	pH	7.8	7.5	7.5	7.6
mg/l P	Phosphate, Total	0.2	0.3	0.2	0.2
mg/l P	Phosphate, Ortho	0.15	0.1	<0.1	0.1
mg/l Mn	Manganese	194	172	146	139
mg/l Cl	Chloride	0.13	0.15	0.15	0.14
mg/l	Solids - Dissolved	13	6	8.1	6
mg/l SO ₄	Sulfate	18	13	13	9.5
Deg C	Temperature	12	15	14	13
NTU	Turbidity	3.8	4.5	6	4

Table 28. Water Quality Monitoring Data

Forrestal Campus, Princeton University					
Station: W5 (C-Site Underground Well)					
	Collection Date -->	3/20/89	6/19/89	9/28/89	12/20/89
Units	Parameter	2:30 PM	1:10 PM	12:35 PM	12:20 PM
mg/l CaCO ₃ eq	Alkalinity	55	51	51	54
mg/l CaCO ₃ eq	Calcium Hardness	35	31	34	33
mg/l Cu	Copper	<0.02	<0.02	<0.02	<0.02
MPN/100 ml	Total Coliform Count	<2	<2	<2	<2
mg/l Fe	Iron	0.41	0.8	0.26	0.18
mg/l N	Nitrogen, Total Kjeldahl	0.54	0.25	0.48	0.28
mg/l N	Nitrogen, Nitrate	1.3	1.6	2.7	1.2
unit	pH	6.4	6.3	6.2	6.5
mg/l P	Phosphate, Total	0.2	0.2	0.2	0.2
mg/l P	Phosphate, Ortho	0.15	0.1	0.1	0.1
mg/l	Solids - Dissolved	119	119	83	87
mg/l Mn	Manganese	0.02	0.01	<0.01	<0.01
mg/l Cl	Chloride	15	3.5	3.8	5
mg/l SO ₄	Sulfate	19	17	14	12
Deg C	Temperature	12	13	13	12
NTU	Turbidity	2.5	3.3	1.8	2.6

Table 29. Water Quality Monitoring Data

Forrestal Campus, Princeton University				
Station: TW1 (Test Well #1 D-Site)				
	Collection Date -->	2/28/89	5/26/89	9/5/89
Units	Parameter	12:20 PM	11:40 AM	11:10 AM
mg/l CaCO3 eq.	Alkalinity	153	150	155
mg/l CaCO3 eq.	Calcium Hardness	80	115	107
mg/l Cu	Copper	<0.02	<0.02	<0.02
MPN/100 ml	Total Coliform Count	15	<2	8
mg/l Fe	Iron	0.4	0.45	0.62
mg/l N	Nitrogen, Total Kjeldahl	0.3	<0.1	0.24
mg/l N	Nitrogen, Nitrate	0.07	0.08	0.61
unit	pH	7.3	7.1	7.4
mg/l P	Phosphate, Total	<0.1	<0.1	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1
mg/l	Solids - Dissolved	239	250	260
mg/l	Manganese	0.15	0.08	0.04
mg/l	Chloride	8	15	15
mg/l	Sulfate	20	31	19
Deg C	Temperature	11.5	17	18
NTU	Turbidity	2.7	7.7	3.6

Table 30. Water Quality Monitoring Data

Forrestal Campus, Princeton University				
Station: TW10 (Test Well #10 D-Site)				
	Collection Date -->	2/27/89	5/26/89	9/6/89
Units	Parameter	3:50 PM	2:00 PM	1:00 PM
mg/l CaCO3 eq.	Alkalinity	152	148	154
mg/l CaCO3 eq.	Calcium Hardness	116	116	109
mg/l Cu	Copper	<0.02	<0.02	<0.02
MPN/100 ml	Total Coliform Count	<2	<2	<2
mg/l Fe	Iron	1.4	1.2	1.52
mg/l N	Nitrogen, Total Kjeldahl	<0.1	0.21	<0.1
mg/l N	Nitrogen, Nitrate	0.03	0.02	0.06
unit	pH	7.3	6.8	7.8
mg/l P	Phosphate, Total	<0.1	<0.1	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1
mg/l	Solids - Dissolved	241	226	250
mg/l	Manganese	0.32	0.5	0.27
mg/l	Chloride	15	14	14
mg/l	Sulfate	19	20	16
Deg C	Temperature	11.5	16.5	18
NTU	Turbidity	9.5	12	12

Table 31. Ground Water Quality Monitoring Data - VO

Forrestal Campus, Princeton University									
Ground Water Volatile Organics									
Sampling Date: 12/12/89									
Units	Parameter	PW-5	PW-4	D-11	D-12	TW-3	Trip Blank	Field Blank	Lab Blank
ug/l	1,1,1-Trichloroethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,1,2,2-Tetrachloroethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,1,2-Trichloroethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,1-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,1-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,2-Dichlorobenzene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,2-Dichloroethane (Total)	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,2-Dichloropropane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,3-Dichlorobenzene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	1,4-Dichlorobenzene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	2-Butanone	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	2-Chloroethylvinylether	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	2-Hexanone	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	4-Methyl-2-Pentanone	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Acetone	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Acrolein	<50	<50	<50	<50	<50	<50	<50	<50
ug/l	Acrylonitrile	<50	<50	<50	<50	<50	<50	<50	<50
ug/l	Benzene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Bromodichloromethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Bromoform	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Bromomethane	<10	<10	<10	<10	<10	<10	<10	<10
ug/l	Carbon Disulfide	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Carbon Tetrachloride	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Chlorobenzene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Chloroethane	<10	<10	<10	<10	<10	<10	<10	<10
ug/l	Chloroform	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Chloromethane	<10	<10	<10	<10	<10	<10	<10	<10
ug/l	Cis-1,3-Dichloropropene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Dibromochloromethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Ethylbenzene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Methylene Chloride	<5	<5	<5	10B	48J	<5	<5	28
ug/l	Styrene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Tetrachloroethane	<5	<5	5	<5	28	<5	<5	<5
ug/l	Toluene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Total Xylenes	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Trans-1,3-Dichloropropene	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Trichloroethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Trichlorofluoromethane	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Vinyl Acetate	<5	<5	<5	<5	<5	<5	<5	<5
ug/l	Vinyl Chloride	<10	<10	<10	<10	<10	<10	<10	<10
B = Contaminant found in blank									
J = Estimated value (detected below quantitation limits)									

Table 32. Ground Water Quality Monitoring Data

Forrestal Campus, Princeton University										
Ground Water Sampling										
Sampling Date: 11/29/89										
Units	Parameter	TW1	TW10	D12	MW14	MW15	MW16	D11	TW2	TW3
mg/l	Alkalinity	154	157							
mg/l	Calcium Hardness	102	112							
mg/l	Copper	<0.02	<0.02							
mg/l	Coliform Total	<2.0	<2.0							
mg/l	Iron	15	4.6							
mg/l	Kjeldahl Nitrogen Total	1.3	1.2							
mg/l	Nitrate	0.37	0.16							
mg/l	pH	7.7	8							
mg/l	Phosphate Total	0.4	<0.1							
mg/l	Ortho Phosphate	<0.1	<0.1							
mg/l	Solids, Dissolved Total	165	238							
mg/l	Manganese	0.1	0.27							
mg/l	Chloride	10	12							
mg/l	Sulfate	12	16							
mg/l	Temperature	.	.							
mg/l	Turbidity	24	11							
mg/l	Chromium, Hexavalent			<0.02	<0.02	<0.02	<0.02			
mg/l	Chloride			24	5	10	6	23	8	12
mg/l	Conductance, Specific			305	90	310	89	480	380	350
mg/l	Sulfate			14	16	34	10	18	29	4.5
mg/l	Solids, Dissolved Total			200	71	202	136	265	266	239
mg/l	Lead			0.14	<0.02	<0.02	<0.02	1.8	<0.02	<0.02
mg/l	Nitrate Nitrogen			0.06	1.4	0.95	0.98	0.87	0.52	0.2
mg/l	Phenols (distillation)			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
mg/l	Ammonia Nitrogen			<0.1	<0.1	<0.1	<0.10	<0.10	<0.10	<0.1

Table 33. Quality Monitoring Data Quality Assurance Checks

		Forrestal Campus, Princeton University							
		Quality Control Samples							
		QA-1	QA-2	QA-1	QA-2	QA-1	QA-2	QA-1	QA-2
Units	Collection Date --> Parameter	2/27/89 11:00 AM	2/27/89 11:00 AM	5/26/89 11:30 AM	5/26/89 11:30 AM	9/6/89 10:30 AM	9/6/89 10:30 AM	11/21/89 10:30 AM	11/21/89 --
mg/l CaCO ₃ eq.	Alkalinity	9.1	4.6	48	48	80	78	59	59
mg/l O ₂	SCD	<2	2	2	<2	1	<1	1	<1
mg/l CaCO ₃ eq.	Calcium Hardness	13	11.2	48	50	61	62	49	49
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	COD	2	19	3	<2	18	16	<5.0	<5.0
mg/l Cu	Copper	<0.02	<0.02	<0.02	<0.02	0.05	0.06	<0.02	<0.02
mg/l O ₂	Dissolved Oxygen	10.4	11	9.6	9.5	12.2	12.2	9.4	9.5
mg/l Cu eq.	EDTA	0.06	<0.02	0.1	0.16	0.32	0.3	0.14	0.16
MPN/100 ml	Total Coliform Count	300	500	220	350	220	240	70	50
ft ³ /sec	Flow	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
mg/l Fe	Iron	0.28	0.29	0.33	0.32	0.13	0.18	0.16	0.16
mg/l N	Nitrogen, Total Kjeldahl	1	0.69	0.41	0.47	0.6	<0.10	<1.0	1.2
mg/l N	Nitrogen, Nitrate	0.73	0.75	1.1	1.1	1.2	1.8	1.1	1.1
mg/l	Oil & Grease	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.3
unit	pH	6.8	6.8	7.2	7.2	8.2	8.2	6.9	7
mg/l P	Phosphate, Total	<0.1	<0.1	0.7	0.7	0.6	0.6	0.25	0.25
mg/l P	Phosphate, Ortho	<0.1	<0.1	0.25	0.25	0.35	0.35	0.15	0.15
mg/l	Solids - Dissolved	113	109	170	175	190	209	111	71
mg/l	Solids - Suspended	3	<1	5	5	3	5	<1	<1
mg/l SO ₄	Sulfate	17	21	28	26	18	18	22	24
Deg C	Temperature	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NTU	Turbidity	6	6.4	3.5	4	1.9	2.4	2.8	2.7
mg/l Zn	Zinc	0.04	0.05	0.04	0.03	<0.02	<0.02	0.03	0.02
	Clarity	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A = Not Applicable									

Table 34

FERTILIZER, PESTICIDES, AND HERBICIDE APPLICATION [Ra90]

FERTILIZER

<u>DATE</u>	<u>LOCATION</u>	<u>PRODUCT</u>	<u>AMOUNT</u>
4/20/89	C & D Sites	Morral 16-0-4	1000 lbs

PESTICIDES

C Site	No pesticides applied
D Site	No pesticides applied

HERBICIDES

<u>DATE</u>	<u>LOCATION</u>	<u>PRODUCT</u>	<u>AMOUNT</u>
4/20/89	C & D Sites All turfed areas	Trimec 899	1.95 gals. 1 gal. per 100 gal. water
5/20/89	C & D Sites Nonturfed areas	Round-Up*	4.0 gals. 6.0 ozs. per gal. water
8/5/89	C & D Sites Nonturfed areas	Round-Up*	3.0 gals. 6.0 ozs. per gal. water

* Round-Up applications were done on selected nonturfed areas — primarily stoned parking lots and road shoulders. Round-Up applications were prohibited in the detention basin and areas surrounding it.

Table 35. PPPL REML QA/QC from EPA/Las Vegas and DOE/EML*

Radioisotope	pCi/L Known Value	pCi/L Control Limits	pCi/L PPPL Values
DATE-->	2/10/89 - EPA Las Vegas		
Cr-51	235	193 to 277	249
Co-60	10	1 to 19	12
Zn-65	159	131 to 187	176
Ru-106	178	147 to 209	182
Cs-134	10	1 to 19	11
Cs-137	10	1 to 19	12
DATE-->	4/18/89 - EPA/Las Vegas		
Cs-134	20	11 to 29	24
Cs-137	20	11 to 29	24
DATE-->	6/9/89 - EPA/Las Vegas		
Ba-133	49	40 to 58	57
Co-60	31	22 to 40	34
Zn-65	165	136 to 194	188
Ru-106	128	105 to 151	145
Cs-134	39	30 to 48	42
Cs-137	20	11 to 29	23
DATE-->	10/6/89 - EPA/Las Vegas		
Ba-133	59	49 to 69	59
Co-60	30	21 to 39	30
Zn-65	129	106 to 152	134
Ru-106	161	133 to 189	157
Cs-134	29	20 to 38	28
Cs-137	59	50 to 68	55
Date-->	7/5/89 EML/DOE NYC		
H-3	6310		5800
Mn-54	300		330
Co-57	880		640
Co-60	940		930
Cs-134	273		260
Cs-137	255		280
DATE	Tritium in Water- EPA/Las Vegas		
2/24/89	2754	2137 to 3371	2740
6/23/89	4503	3724 to 5282	4673
10/20/90	3496	2866 to 4126	3360

* REML = PPPL Radiological Environmental Monitoring Laboratory

EPA/Las Vegas = Environmental Protection Agency's Laboratory in Las Vegas

DOE/EML = The Department of Energy's Environmental Measurements Lab in New York City

Table 36. Precipitation at PPPL for 1989

Week	Inches	Start Date	Inch/Month	Month	Accumulation
1	0.35	2-Jan			0.35
2	1.05	10-Jan			1.4
3	0	16-Jan			1.4
4	0.05	23-Jan			1.45
5	0.6	30-Jan	2.05	JAN	2.05
6	0.075	6-Feb			2.125
7	0.95	13-Feb			3.075
8	1.75	20-Feb			4.825
9	0.15	27-Feb	2.925	FEB	4.975
10	0.4	6-Mar			5.375
11	0.35	13-Mar			5.725
12	1.45	20-Mar			7.175
13	0.95	27-Mar	3.15	MAR	8.125
14	0.95	3-Apr			9.075
15	1.05	10-Apr			10.125
16	0.1	17-Apr			10.225
17	0.25	24-Apr	2.35	APR	10.475
18	3.125	1-May			13.6
19	2.15	8-May			15.75
20	2.4	15-May			18.15
21	1.5	22-May			19.65
22	0.475	29-May	9.65	MAY	20.125
23	3.425	5-Jun			23.55
24	0.925	12-Jun			24.475
25	0.615	19-Jun			25.09
26	0.4	26-Jun	5.365	JUNE	25.49
27	5.15	3-Jul			30.64
28	2.05	10-Jul			32.69
29	1.55	17-Jul			34.24
30	0.4	24-Jul			34.64
31	0.3	31-Jul	9.45	JULY	34.94
32	1.45	7-Aug			36.39
33	0.15	14-Aug			36.54
34	0.2	21-Aug			36.74
35	0	28-Aug	1.8	AUG	36.74
36	0	4-Sep			36.74
37	1.15	11-Sep			37.89
38	8.65	18-Sep			46.54
39	0.88	25-Sep	10.68	SEPT	47.42
40	1.025	2-Oct			48.445
41	0.025	9-Oct			48.47
42	3.48	16-Oct			51.95
43	0.025	23-Oct			51.975
44	0.55	30-Oct	4.555	OCT	52.525
45	0.9	6-Nov			53.425
46	0.42	13-Nov			53.845
47	0.3	20-Nov			54.145
48	0.25	27-Nov	1.87	NOV	54.395
49	0.075	4-Dec			54.47
50	0.075	11-Dec			54.545
51	0	18-Dec			54.545
52	0.8	25-Dec	0.95	DEC	55.345

Table 37. Tritium in Water Samples

Location-->	B1	B2	C1	D1	D2	E1	M1	P1	P2	W4	W5	Rain Dates	Precipitation	
Collection Date	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L		pCi/L	
1/10/89	48	53	60	60	72	57	50	63	57	57	55	1/2 to 1/31	28 8/7 to 8/14	48
2/2/89	66	57	65	58	53		50	57	44	44	63	1/31 to 3/1	48 8/14 to 8/21	47
2/24/89	54	41	39	53	54	55	46	50	37	41	73	2/20 to 2/21	21 8/21 to 8/28	48
												3/1 to 3/20	60 8/28 to 9/5	no rain
3/14/89	52	58	60	65	65	67	57	68	75	50	69	3/8 to 3/8	38 9/5 to 9/11	no rain
4/11/89	52	51	59	56	53	56	69	63	57	35	64	3/20 to 3/28	35 9/11 to 9/18	28
5/4/89	52	65	61	60	62	47	71	67	67	31	71	3/31 to 4/10	90 9/18 to 9/25	<MDA*
5/23/89	44	58	55	56	56	58	52	54	50	35	58	4/10 to 4/17	91 9/25 to 10/2	15
6/19/89	46	47	64	66	59	61	50	34	56	49	57	4/17 to 5/1	84 10/2 to 10/9	no rain
7/11/89	58	58	61	54	57	58	45	47	48	50	59	5/1 to 5/22	44 10/9 to 10/16	21
8/2/89	55	58	61	57	59	60	52	53	59	45	58	5/22 to 5/30	29 10/16 to 10/23	30
8/22/89	62	59	62	63	59	60	56	59	58	46	61	5/30 to 6/5	49 10/30 to 11/6	28
9/12/89	62	62	50	66	66	63	57	58	58	48	55	6/5 to 6/12	37 11/6 to 11/13	44
10/5/89	57	33	49	45	47	55	32	40	37	53	54	6/12 to 6/19	46 11/13 to 11/20	16
10/24/89	41	39	36	41	41	49	36	41	37	54	56	6/19 to 6/26	22 11/20 to 11/27	50
11/14/89	43	41	46	43	38	44	44	44	43	47	54	6/26 to 7/10	34 11/27 to 12/5	63
12/5/89	48	51	52	47	51	45	47	52	51		55	7/10 to 7/17	89 12/5 to 12/11	no rain
												7/24 to 7/31	70 12/11 to 12/18	99
*MDA=7 pCi/L												7/31 to 8/7	54 12/18 to 1/2	32

Table 39. NJDEP Environmental Permits

	NJDEP permit No.	Type	Issue date	Expiration date	Status
1	23922	NJPDES Groundwater	4/1/89	5/1/94	In compliance. Adjudiciary hearing pending.
2	23922	NJPDES Surface water	9/28/84	10/31/89	Renewal applied for, awaiting response.
3	92187	TFTR Diesel Exhaust	10/24/89	10/24/94	Current
4	90734	TFTR Hot Cell Degreaser	12/8/88	12/2/89	Degreaser moved from CAS Fld., awaiting NJDEP inspection. Permit extended until inspection.
5	90735	FCPC Building Degreaser Vent	12/2/88	12/2/89	Awaiting NJDEP inspection. Permit extended until inspection.
6	826	Elizabethtown Water	3/31/90	3/31/91	Current
7	148539	Underground Storage Tanks	3/1/88	3/31/90	Current, alterations made to reflect removal of tanks. Permit renewal applied for.
8	89962	Diesel Tank E8 Vent	11/11/88	11/22/93	Current, will be modified to reflect removal of underground storage tanks.
9	89961	Unleaded Gasoline UST E2 Vent	12/13/88	12/13/93	Current, will be modified to reflect removal of underground storage tanks.
10	61294	Boiler #1 Stack Vent	3/31/82	3/31/92	Current
11	61295	Boiler #2 Stack Vent	3/31/82	3/31/92	Current
12	61296	Boiler #3 Stack Vent	3/31/82	3/31/92	Current
13	61297	Boiler #4 Stack Vent	3/31/82	3/31/92	Current
14	61298	Oil Storage Tank Vent No. 2	3/31/82	3/31/92	Current, will be modified to reflect removal of underground storage tanks.
15	61299	Boiler #5 Stack Vent	3/31/82	3/31/92	Current, will be changed to reflect removal of boiler.
16	61300	Oil Storage Tank Vent No. 1	3/31/82	3/31/92	Current, will be modified to reflect removal of underground storage tanks.
17	-	Diesel Exhaust C-site	-	-	Application under review.
18	-	Medical Waste Generator	12/1/89	12/1/90	Current

Table 40. Summary of 1989 Airborne Emissions and Doses from TFTR

Radionuclide & Pathway	Quantity Released in 1989 ¹	EDE at the Site Boundary	EDE at the Nearest Business ²	Population Dose Within 80 km ³
Tritium (HTO) [air]	0.31 Ci ⁴	7×10^{-4} mrem ⁵	2×10^{-4} mrem ⁶	1×10^{-2} person-rem ⁷
⁴¹ Ar	0.53 Ci ⁸	2×10^{-3} mrem ⁹	6×10^{-4} mrem ⁶	3×10^{-3} person-rem ¹⁰
Direct & Scattered Neutrons and Gamma radiation	-----	Background ¹¹	Background ¹¹	Background ¹¹
Tritium (HTO) [water]	5.2×10^{-4} Ci ¹²	1×10^{-5} mrem ¹³	-----	-----
Total	-----	2.71×10^{-3} mrem	8.0×10^{-4} mrem	1.3×10^{-2} person-rem
Background	-----	360 mrem	360 mrem	1.6×10^6 person-rem

Footnotes:

¹ Based on production of 6.4×10^{18} neutrons in 1989.² At Princeton Bank Building, 351 meters east of TFTR stack.³ Based on year 2000 population figures as utilized for CIT EA. Population in every sector is projected to be higher in year 2000 than in 1985 (See Tables 4-15 [Be87a]).⁴ As per letter Stencel, PPPL, to Mix, DOE, on 4/9/90, "Radionuclide Emission Standards - 40 CFR Part 61, and Calendar Year 1989 Reports," JRS-1734.⁵ Based on NOAA χ/Q [Si89a]; $0.31 \text{ Ci} \times 2.4 \times 10^{-3} \text{ mrem/Ci}$.⁶ Based on 28% of the NOAA χ/Q at the site boundary [Si89a].⁷ Scaling from Table 7 of INEL Report [Mc89], we get $(0.31 \text{ Ci}/500 \text{ Ci}) \times 16.5 \text{ person-rem} = 1 \times 10^{-2} \text{ person-rem}$.⁸ As per letter, Stencel, PPPL, to Mix, DOE, 5/4/90, "Radionuclide Emission Standards - 40 CFR Part 61, and Calendar Year 1989 Reports," JRS-1757.⁹ As per letter, Stencel, PPPL, to Mix, DOE, 5/4/90, "Radionuclide Emission Standards - 40 CFR Part 61, and Calendar Year 1989 Reports," JRS-1757, and based on NOAA χ/Q [Si89a]; $1.7 \times 10^{-3} \text{ mrem} \times (1.77 \times 10^{-5} \text{ s/m}^3 / 1.5 \times 10^{-5} \text{ s/m}^3)$.¹⁰ Scaling from Table 7 of INEL Report [Mc89], we get $(0.53 \text{ Ci}/49 \text{ Ci}) \times 0.3 \text{ person-rem} = 3 \times 10^{-3} \text{ person-rem}$.¹¹ As per PPPL internal report [Gi90].¹² Released from Liquid Effluent Collection Tanks (LECT) to Stony Brook Sewer Authority treatment facility via PPPL sanitary sewer system.¹³ Based on usage of 9.95×10^9 liters/y for Stony Brook treatment facility as per Section 3.2 of INEL Report [Mc89], the dose to a person who drank all his/her water from the waterway (Millstone River) into which the treatment facility discharge in 1989 would be $5.2 \times 10^{-4} \text{ Ci/y} / 9.95 \times 10^9 \text{ liters/y} \times 4 \text{ mrem/2} \times 10^{-8} \text{ Ci/liter} = 1 \times 10^{-5} \text{ mrem}$.

Figure 1. The Princeton Beta Experiment - Modified (PBX-M)

Figure 2. The Molokai Point Dam Dam (1973)

Wind Rose
 Joint Frequency Data for TFTR
 84/ 1 to 89/12
 Elevation 30 m
 For All Stability Classes (100.0%)

Wind Speed (m/s)

7.0	■	and above
2.0	■	to 7.0
1.0	■	to 2.0
0.75	■	to 1.0
0.50		to 0.75
0.22		to 0.50

Center = Calm %

Figure 3. Wind Rose at 30 m.

Wind Rose
 Joint Frequency Data for TFTR
 84/ 1 to 89/12
 Elevation 60 m
 For All Stability Classes (100.0%)

Wind Speed (m/s)

7.0	■	and above
2.0	■	to 7.0
1.0	■	to 2.0
0.75	■	to 1.0
0.50	■	to 0.75
0.22	■	to 0.50

Center = Calm %

Figure 4. Wind Rose at 60 m.

Figure 5. The Forrestal Campus

Figure 7. 80 km (50-mile) Radius of Site

Figure 8. Immediate Site Vicinity (5-Mile Radius)

Figure 9. James Forrestal Campus
Princeton University
Princeton, New Jersey

Princeton Plasma Physics

1985 POPULATION ESTIMATES
WITHIN 10 MILES
0 - 10 MILES
Figure 10

Princeton Plasma Physics

1988 POPULATION PROJECTIONS
WITHIN AZIMUTHAL REGIONS
0 - 10 MILES

Figure 11

*Taken from Be87a

Princeton Plasma Physics

2000 POPULATION PROJECTIONS
 WITHIN ANNUAL SECTIONS
 0 - 10 MILES

Figure 12

*Taken from DeB7a

Princeton Plasma Physics
2005 REPLICATION PROJECTIONS
WINDMILL ANNUAL SECTIONS
0 - 10 MILES

Figure 13

*Taken from Be87a

Princeton Plasma Physics

2040 POPULATION PROJECTIONS
WITHIN ANGULAR SECTORS
0 - 10 MILES

Figure 14

Princeton Plasma Physics

ION POPULATION ESTIMATES
WITHIN 10-50 MILES

Figure 15

*Taken from DeBj/a

1985 POPULATION ESTIMATES
WITHIN ARABIAN SECTOR
10 - 50 MILES

*Taken from Be87a

Princeton Plasma Physics

2000 POPULATION ESTIMATES
WITHIN ANNUAL SECTIONS
10 - 10 MILES

Figure 17

*Taken From Be87a

Princeton Plasma Physics

2005 POPULATION ESTIMATES
WITHIN AZIMUTHAL SECTORS
10 - 40 MILES
Figure 18

*Taken from Be87a

Princeton Plasma Physics

2010 POPULATION ESTIMATES
WITHIN AZIMUTHAL SECTORS
10 - 50 MILES

Figure 19

*Taken from Be87a

Figure 20. C- and D-Sites and Environmental Monitoring Locations

FIG. 21. Millstone River Basin Offsite Water Sample Locations

Figure 22. Potentiometric surface of the bedrock aquifer, October 30, 1986.
(Taken from Le87)

Figure 23. Schematic representation of hydrogeologic framework and potential flow paths of spilled water. (Taken from Le87).

Figure 24. Precipitation at PPPL in 1989

Figure 25. Tritium in Precipitation at PPPL -1989

Figure 26. Soil Tritium Level in 1989

Figure 27. Off-Site Monitoring Locations